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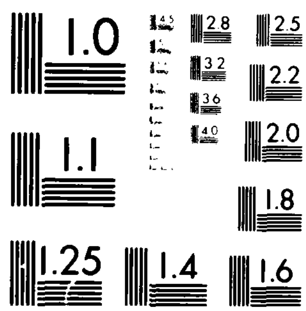

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Bethesda, Maryland 20084

DTNSRDC/SPD-0840-01

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PROGRAM PHFMOPT

PLANING HULL FEASIBILITY MODEL

USER'S MANUAL

by

E. NADINE HUBBLE

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SHIP PERFORMANCE DEPARTMENT REPORT

PROGRAM PHFMOPT PLANING HULL FEASIBILITY MODEL USER'S MANUAL

DECEMBER 1978

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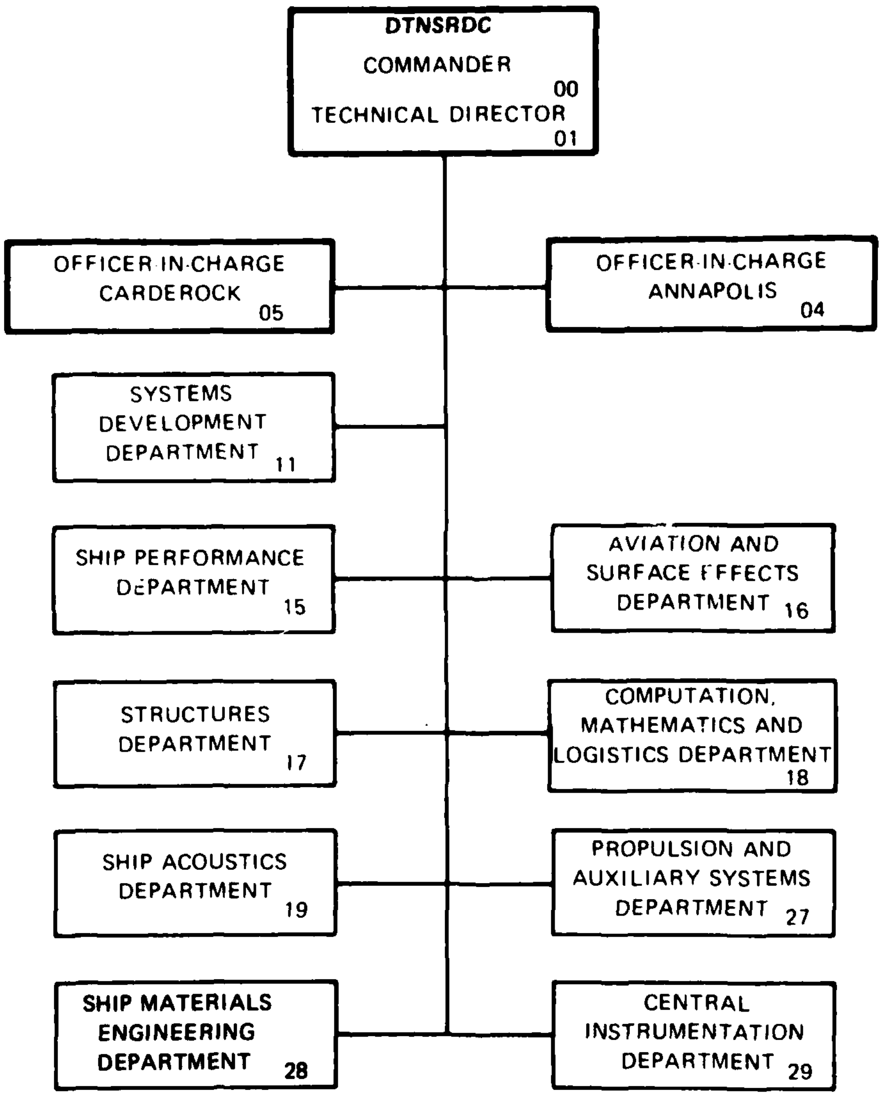

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Documentation of a computer program for performing design feasibility studies of planing hulls is presented. The mathematical model is oriented to combatant craft but may also be applied to other types of planing ships with full-load displacement up to 1500 tons and speed-displacement coefficient $F_{n\nabla}$ up to 4. Options are available for structural materials of aluminum or steel or glass reinforced plastic, diesel or gas turbine prime movers with or without auxiliary engines of either type, and propellers on inclined shaft or waterjet pumps. Weight, volume, and vertical center of gravity for the major

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ship components, including loads, are estimated. Hull size may either be fixed or optimized to meet design payload requirements.

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NOTATION

$\overline{AG}$	Longitudinal distance of center of gravity forward of transom (also referred to as LCG)
A_I	Open area of waterjet pump inlet
A_J	Jet area of waterjet pump
A_P	Projected planing bottom area
$A_P/\nabla^{2/3}$	Loading coefficient
$\overline{BM}$	Height of metacenter above center of buoyancy
B_{PA}	Average breadth over chines
B_{PX}	Maximum breadth over chines
BSCI	U.S. Navy weight identification system; Bureau of Ships Consolidated Index of Drawings, Materials and Services related to Construction and Conversion of Ships, February 1965
CG	Center of gravity
CODOG	Combination of diesel or gas turbine propulsion; gas turbine prime movers designed for maximum speed and auxiliary diesels designed for cruise speed
COGOG	Combination of gas turbine prime movers for maximum speed or auxiliary gas turbines for cruise speed
C_Δ	Beam loading coefficient $=\Delta/(\rho g B_{PX}^3) = \nabla/B_{PX}^3$
D	Propeller diameter or waterjet impeller diameter
EAR	Propeller expanded area ratio
$F_{n\nabla}$	Speed-displacement coefficient $= V/(g\nabla^{1/3})^{1/2}$ Also referred to as volume Froude number
g	Acceleration of gravity
$\overline{GM}$	Metacentric height; height of metacenter above CG
GRP	Glass reinforced plastic, i.e., fiberglass
H_h	Hull depth at midships; baseline to main deck
$H_{1/3}$	Significant wave height
IHR	Inlet head recovery of waterjet pump
$\overline{KB}$	Height from baseline to center of buoyancy
$\overline{KG}$	Height from baseline to center of gravity of ship (also referred to as VCG)
K_T/J^2	Propeller thrust loading

L/B	Hull length/beam ratio = L_P/B_{PX}
L_P	Projected chine length
L_{OA}	Overall length of ship
$L_P/\nabla^{1/3}$	Slenderness ratio
N	Rotational speed; RPM
NPSH	Net positive suction head of waterjet pump
OPC	Overall performance coefficient = P_{E_b}/P_D
P/D	Propeller pitch ratio
p_A	Atmospheric pressure
P_c	Total brake power required at cruise speed
P_d	Total brake power required at design speed
P_D	Total power delivered at propellers or waterjets
P_E	Effective power
P_{E_b}	Effective power of bare hull
p_H	Static water pressure on rotating axis of propeller or waterjet pump
p_V	Vapor pressure
Q	Torque on propeller shaft
Q	Mass flow of waterjet pump = $A_J V_J = A_I V_I$
Q_c	Propeller torque load coefficient
R	Resistance
R/W	Resistance/weight ratio
$S/\nabla^{2/3}$	Wetted area coefficient
S_s	Suction specific speed of waterjet pump
SFC	Specific fuel consumption
T	Thrust
T	Draft at midships; baseline to waterline
V_c	Cruise (range) ship speed
V_d	Design (maximum) ship speed
V_I	Average flow velocity into waterjet pump inlet
V_J	Jet velocity of pump at operating ship speed = $V_{JB} + \Delta V_J$

V_{JB}	Jet velocity of pump at bollard condition, i.e., zero ship speed
V_S	Operating ship speed
W	Total weight of ship = displacement
W_1	Weight of hull structures, BSCI Group 1
W_2	Weight of propulsion system, BSCI Group 2
W_3	Weight of electric plant, BSCI Group 3
W_4	Weight of nonmilitary communication and control, BSCI Group 4
W_5	Weight of auxiliary systems, BSCI Group 5
W_6	Weight of outfit and furnishings, BSCI Group 6
W_{CE}	Weight of crew and effects, provisions, and water
W_F	Weight of fuel
W_P	Weight of payload
W_P/∇_P	Payload density
X	Distance forward of transom
Y_C	Half-breadth at chine
Y_K	Half-breadth at keel
Y_S	Half-breadth at main deck
Z_C	Height of chine above baseline
Z_K	Height of keel above baseline
Z_S'	Height of main deck above baseline
$1-t$	Thrust deduction factor
$1-w$	Wake factor
β	Deadrise angle of hull bottom from horizontal
γ	Angle of hull sides from vertical
γ_{mat}	Density of structural material
Δ	Ship displacement = $\rho g \nabla$
Δ_{LT}	Full-load displacement in long tons
Δ/∇_h	Vehicle density
ΔV_J	Increase in jet velocity due to inlet head recovery

ϵ	Shaft angle from baseline
η_a	Appendage drag factor
η_D	Propulsive coefficient = P_E/P_D
η_O	Propeller efficiency
ν	Viscosity of water
ρ	Water density
σ	Propeller cavitation number based on advance velocity
σ	Standard deviation
σ_{limit}	Stress limit of structural material
σ_{TIP}	Waterjet impeller tip velocity cavitation number
$\sigma_{0.7R}$	Cavitation number based on resultant water velocity at 0.7 radius of propeller
τ_c	Thrust load coefficient for propeller or waterjet
∇	Displaced volume
∇_h	Hull volume up to main deck
∇_P	Volume of payload inside of hull and superstructure
∇_{ss}	Volume inside superstructure
∇_T	Total volume = $\nabla_h + \nabla_{ss}$

ABSTRACT

Documentation of a computer program for performing design feasibility studies of planing hulls is presented. The mathematical model is oriented to combatant craft but may also be applied to other types of planing ships with full-load displacement up to 1500 tons and speed-displacement coefficient $F_{n\nabla}$ up to 4. Options are available for structural materials of aluminum or steel or glass reinforced plastic, diesel or gas turbine prime movers with or without auxiliary engines of either type, and propellers on inclined shafts or waterjet pumps. Weight, volume, and vertical center of gravity for the major ship components, including loads, are estimated. Hull size may either be fixed or optimized to meet design payload requirements.

ADMINISTRATIVE INFORMATION

Modifications for the current program were authorized and funded by the Naval Sea Systems Command, Detachment Norfolk (NAVSEADET Norfolk) Project Order 00016. The work was performed at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) under Work Unit 1-1524-718.

INTRODUCTION

A computer program labeled PHFMOPT has been developed at DTNSRDC and utilized in numerous design feasibility studies by NAVSEADET Norfolk for combatant craft projects such as the Special Warfare Craft, Medium SWCM and Landing Craft LCM-9. The computer software has been revised and updated numerous times to keep abreast of the project requirements and state-of-the-art. This report provides a general description of the present mathematical model together with documentation for each module of the computer program in Appendix A. This program is operable on the Control Data Corporation 6000 Computers at DTNSRDC and has also been recently installed on the Digital Equipment Corporation PDP/8 Computer at NAVSEADET Norfolk. Sample input and output are shown in Appendix B.

The planing hull feasibility model PHFMOPT is applicable for a wide range of planing-hull prototypes with slenderness ratio $L_p/\nabla^{1/3}$ from 4 to 10, speed-displacement coefficient $F_{n\nabla}$ from 0.5 to 4.0, and displacement from 50 to 1500 tons. A comparison of the model with an actual patrol craft and an example of a design study utilizing the model has been presented in Reference 1.

*A complete listing of references is given on page 17.

GENERAL DESCRIPTION OF MODEL

Computer program PHFMOPT estimates the weight, volume, and vertical center of gravity VCG of major components for the empty ship plus the fuel load, crew, and provisions. Then, either (1) the resultant weight, volume, and VCG of the payload is computed for a hull of fixed size, or (2) the hull depth H_h, maximum chine beam B_{PX}, and/or displacement Δ_{LT} are optimized to meet design payload requirements for a ship of fixed length L_P. Computations may be made for several values of L_P to determine the optimum ship length.

Ship components for the U.S. Navy Bureau of Ships Consolidated Index BSCI Groups 1 through 6 are computed at the three-digit level. The data base for the model includes small patrol craft, hydrofoil craft, destroyers DD, and destroyer escorts DE so that planing ships up to 1500 tons can be evaluated. A multiplier (K-factor) is input for each three-digit BSCI group which may be used to modify or eliminate weights and volumes derived from the general equations presented in Appendix A. A K-factor is also applied to the total of each single-digit group, essentially adding a designer's margin.

Input to the program is read by Subroutine READIN and consists of 54 punched data cards which contain offsets for the parent hull form and design constants. Data from the cards are immediately printed for use in checking input errors. In addition, one card for each design condition, containing the length L_P and initial values of Δ_{LT}, B_{PX}, and H_h, is read by the executive routine PHFMOPT. A detailed description of the input and the printed output is presented in Appendix A. Output is controlled by Subroutine PRTOUT.

HULL GEOMETRY

The planing hull is represented by a hard-chine model as shown in Figure 1. Offsets input for the parent hull form are nondimensionalized in Subroutine PARENT. Offsets and hydrostatics for each new design condition of L_P, B_{PX}, and Δ_{LT} are computed by Subroutine NEWHUL. All parametric variations have the same deadrise as the parent, since the keel and chine offsets are proportioned by the average beam B_{PA} and B_{PX}/B_{PA} is held constant. The hull volume below the main deck ∇_h and the hull density

Δ/∇_h are computed by Subroutine NEWVOL for each change in H_h. Slope of the hull sides is maintained whenever deck height is changed.

The general arrangement of the transverse bulkheads, platforms, and fuel tanks employed by the planing hull model is shown in Figure 2. Nine bulkheads positioned as shown are used for planing hulls over 70 tons and should be sufficient for a two-compartment ship aft and a three-compartment ship forward for most configurations. The number of bulkheads is reduced for smaller craft based on existing designs. The general arrangement used for the landing craft model is shown in Figure 3. For this special case, additional input parameters are required to define the well deck and ramps. A maximum of 15 bulkheads may be input, and a spacing of about 6 ft between bulkheads is used under the well deck.

STRUCTURES

The hull structures (BSCI Group 1) are computed in Subroutine STRUCT. The structural design procedure takes into account sea loads and effects of changes in hull length, beam, and depth. The design methodology is based on References 2, 3, and 4 and explained in detail in Reference 1. Structures of either aluminum, steel, or glass reinforced plastic GRP may be computed. Two interchangeable Subroutines STRUCT are available, one for aluminum or steel hulls, the other for single skin or sandwich plate GRP hulls. Curves of structural weight data used by the math model are shown in Figures 4, 5, 6, 7, and 8.

A third Subroutine STRUCT is available for landing craft of aluminum or steel which accounts for the increased load on the well deck and ramps and changes in the internal arrangement.

RESISTANCE

Bare-hull resistance for the feasibility model is estimated from DTNSRDC Series 62 and 65 hard-chine planing hull data published in Reference 5. Mean values of resistance/weight ratio R/W as a function of $L_p/\nabla^{1/3}$ and $F_{n\nabla}$ were computed from the 21 models of the two series with the longitudinal center of gravity LCG position ranging from 1/3 to 1/2 L_p forward of the transom. Mean values of wetted area coefficient $S/\nabla^{2/3}$ were obtained for the same data. Faired curves of the mean R/W for a

100,000-lb planing craft and mean $S/\nabla^{2/3}$ are presented in Figures 9 and 10. Data from the faired curves have been incorporated in Subroutine PHRES (see Tables 1 and 2) so that the mean R/W can be interpolated for $L_P/\nabla^{1/3}$ from 4 to 10 at $F_{n\nabla}$ from 0 to 4 and scaled to the required ship size. Standard deviation σ of the base data from the mean values was also computed and faired as a function of $F_{n\nabla}$. A multiplier SDF may be used with σ to raise or lower the mean R/W data when attempting to match existing resistance data for a particular hull form.

$$\text{Predicted } R/W = \text{Mean } R/W - (\text{SDF} \times \sigma)$$

Resistance of the appendaged hull is estimated by applying an appendage drag factor η_a to the bare-hull resistance. The factor η_a developed by Blount and Fox, Reference 6, is applied only to hulls with propellers on inclined shafts. No increase in resistance is assumed for hulls fitted with waterjets.

Added resistance in rough water R_{aw} is predicted from an empirical equation given in Reference 7 which was developed by a regression of planing hull rough-water experimental data.

$$R_{aw}/\Delta = 1.3 \quad (H_{1/3}/B_{PX})^{0.5} \quad F_{n\nabla} \quad (L_P/\nabla^{1/3})^{-2.5}$$

THRUST

The feasibility model has the option for either propellers on inclined shafts or waterjet pumps. Thrust deduction (1-t) used for the propellers is 0.92 from Blount and Fox, Reference 6. Thrust deduction assumed for waterjets is 0.95. Total thrust requirement $T = R_t/(1-t)$ where R_t is total resistance.

Subroutine PROPS is utilized to estimate the powering requirements for the ship at design and cruise speed when propellers are employed. If not input, the number of propellers is selected based on maximum power of prime movers available. Subroutine PROPS also determines propeller diameter if not specified, selecting the smallest propeller capable of producing the required thrust at both design and cruise speeds, based on an input constant for $\tau_c/\sigma_{0.7R}$. A value of $\tau_c/\sigma_{0.7R} \simeq 0.6$ corresponds to the 10 percent back cavitation criteria for Gawn-Burrill type propellers.

Propeller open-water characteristics are derived as a function of pitch ratio P/D, expanded area ratio EAR, and number of blades Z from polynomials developed from the Wageningen B-Screw Series of airfoil section propellers, Reference 8, or recent modifications of these polynomials for flat face, segmental section propellers such as the Gawn-Burrill Series, Reference 9. Propeller characteristics in the cavitation regime are derived from maximum thrust and torque load coefficient τ_c and Q_c developed as functions of cavitation numbers at the propeller 0.7 radius $\sigma_{0.7R}$ in Reference 10.

Subroutine WJETS is used to estimate the power requirements with waterjet pumps. Waterjets of fixed size may be input, or the waterjets may be designed within the program using the approach given by Denny in Reference 11. The design pumps are assumed to operate at maximum input power and maximum rpm at the ship's design speed. A ratio of bollard jet velocity V_{JB} to ship speed V_S about 2 will result in optimum propulsive efficiency; see Figure 3 of Reference 11. However at low design speeds, e.g., 20 knots, a value of $V_{JB}/V_S > 2$ may be required in order to keep the size of the waterjet within reasonable bounds.

PROPULSION

Once the power estimates are made for design and cruise speeds, the propulsion (BSCI Group 2) components are calculated in Subroutine POWER. The following propulsion systems are available in the computer model:

(1) diesel prime movers,

(2) gas turbine prime movers,

(3) CODOG system -- gas turbine prime movers with auxiliary diesels,

(4) COGOG system -- gas turbine prime movers with auxiliary gas turbines.

There is always one prime mover for each propeller or waterjet. The prime movers are designed to operate at maximum power at the ship's design speed; the auxiliary engines operate at their maximum power at cruise speed.

General equations for specific weight, rotational speed, and specific fuel consumption SFC have been developed for high speed diesels and second generation gas turbines. Data from the general equations may be modified by input constants to match a particular series of engines, or fixed weights and SFC's may be input to the program. Gear weights may be fixed or derived from a general equation developed by Mandel at Massachusetts Institute of Technology with appropriate constants for either single reduction or planetary gears. Propeller and waterjet weights are primarily a function of their size. Subsidiary propulsion system weights are given as a function of the total power of the prime movers.

Volumes required for the engine room, combustion air supply, and uptakes may be fixed inputs or obtained from the general equations based on existing diesel and gas turbine systems.

OTHER SYSTEMS

The electric plant (BSCI Group 3) components are computed in Subroutine ELECPL. The electric power requirement in kilowatts may be an input or computed as a function of the ship displacement.

The nonelectronic navigation equipment and interior communication system are established in Subroutine COMCON. The remainder of communication and control (BSCI Group 4) is considered part of the payload.

Auxiliary systems (BSCI Group 5) and the outfit and furnishings (BSCI Group 6) are computed in Subroutines AUXIL and OUTFIT. The general equations were primarily derived from DD and DE data. However, changes were made for aluminum components in lieu of steel, using 2/3 the weight of steel where equal stress is required and 1/2 the weight of steel where size is maintained.

LOADS

The fuel requirement is established in Subroutine POWER based on the SFC and range at either cruise speed or design speed, whichever dominates. A five percent margin is added for fuel which cannot be utilized. An additional five percent margin is added to the volume of the fuel tanks

to allow for expansion. The fuel tanks are generally an integral part of the hull structure, but an option is available for separate fuel tanks when required.

The ship's complement may either be input or calculated in Subroutine CREWSS based on accommodations of numerous small and intermediate-sized warships. The crew concerned with the military payload is included in the total complement and not treated as part of the military payload. Weights and volumes of the crew and their effects based on U.S. Navy standard allowances, as well as personnel stores and potable water for the specified accommodations and days at sea, are computed in Subroutine LOADS.

The components of BSCI Groups 1 through 6 are combined and specified margins added in Subroutine TOTALS to obtain the empty ship weight, volume, and VCG. The difference between the full-load displacement and the empty ship weight is termed the useful load, which includes the fuel, crew and provisions, and the payload. The payload consists of the armament (BSCI Group 7), the military portion of communication and control (Group 4), ammunition, and any special loads required for the ship's mission, such as the tanks carried by a landing craft. The computer model does not separate the various components of the payload.

OPTIMIZATION

Unless the hull size is fixed, the executive routine PHFMOPT iterates until the design payload specifications are met, or until a default condition occurs. The ship displacement is increased or decreased until the resultant payload weight W_P is equal to the input value for design payload. The beam of the hull is varied until the specified VCG of the design payload is obtained, maintaining the input metacentric height $\overline{GM}$. The hull depth is raised or lowered to obtain the design payload volume ∇_P (payload density = W_P/∇_P). A flow chart of the optimization process is presented in Appendix A.

Possible default conditions are as follows:

(1) $L_p/\nabla^{1/3}$ less than 4 or greater than 10,

(2) $F_{n\nabla}$ greater than 4,

(3) Δ_{LT}, B_{PX}, or H_h not converging after 10 iterations for each variable.
A default may occur if the initial values of Δ_{LT}, B_{PX}, and H_h are not close to the optimums. Therefore, the program user may be wise to begin a new design with several fixed hull sizes to aid in the selection of initial values for the optimization process.

FINAL HULL

Weights, VCG's, and volumes for the final (or fixed) hull form are printed from Subroutine PRTOUT at the BSCI 3-digit level. Also output are offsets and hydrostatics for the final hull, speed-power predictions for a range of speeds, and some vertical acceleration predictions in various sea states based on empirical equations in Reference 12. A sample printout is shown in Appendix B.

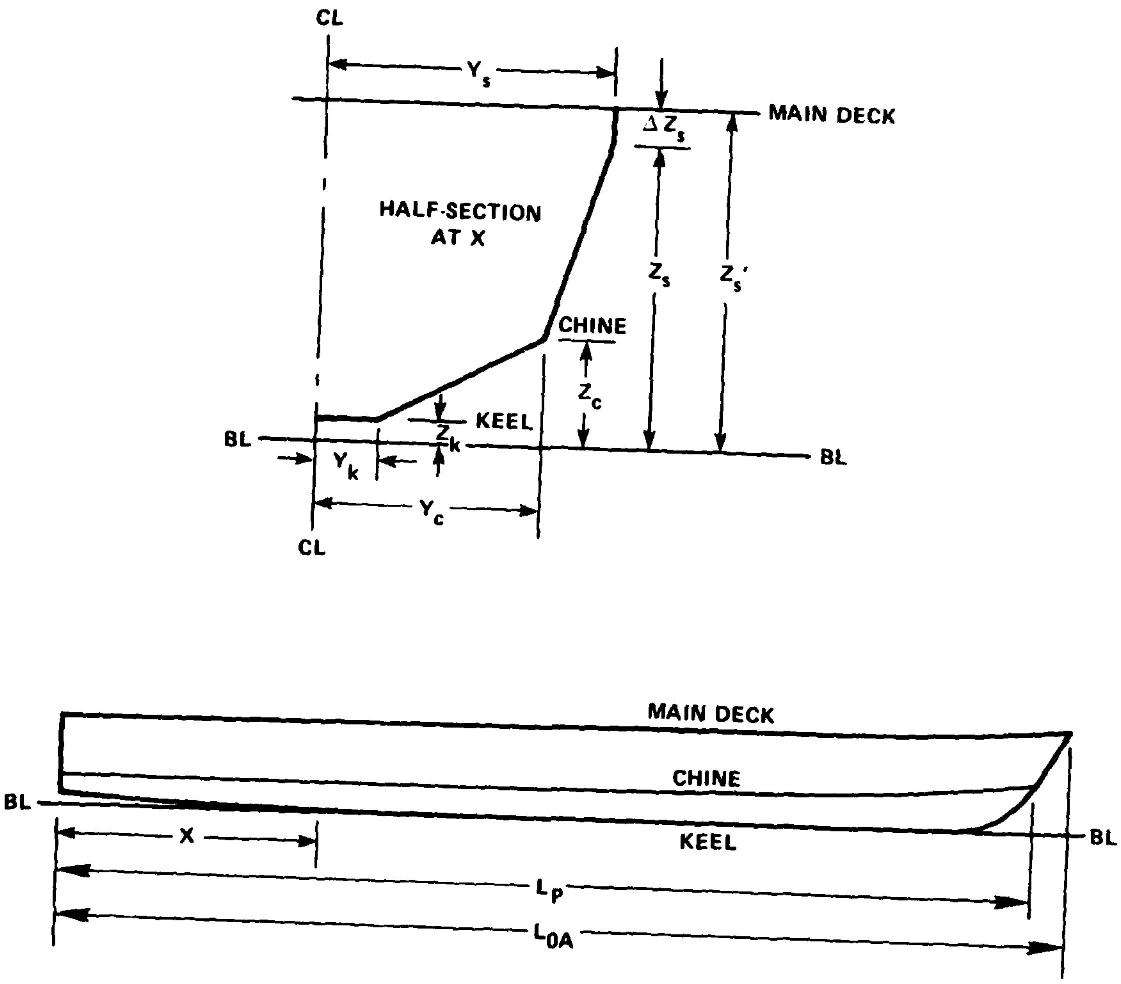
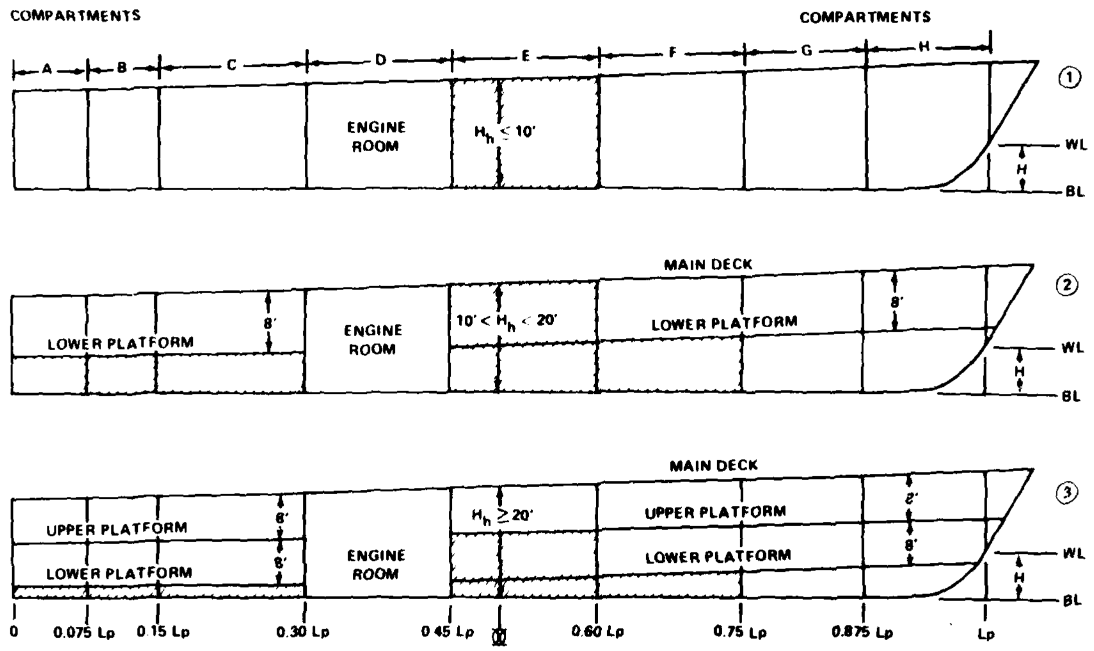


Figure 1 - Geometry of Computer Model for Planing Hull



HULL DEPTH	PLATFORM DECKS	FUEL TANKS
① 10 FT OR LESS	NONE	COMPARTMENT E, KEEL TO MAIN DECK.
② 10 FT – 20 FT	ONE PLATFORM 8 FT BELOW MAIN DECK. EXTENDS FULL LENGTH OF HULL, EXCEPT ENGINEROOM.	COMPARTMENTS A, B, C, E, F BELOW PLATFORM. EXTEND TANK E TO MAIN DECK IF MORE VOLUME REQUIRED
③ 20 FT OR MORE	LOWER PLATFORM 16 FT BELOW MAIN DECK. UPPER PLATFORM 8 FT BELOW MAIN DECK, EXTENDS FULL LENGTH OF HULL, EXCEPT ENGINEROOM.	COMPARTMENTS A, B, C, E, F BELOW LOWER PLATFORM. EXTEND TANK E TO UPPER PLATFORM IF MORE VOLUME REQUIRED.

Figure 2 - General Arrangement of Typical Planing Hull

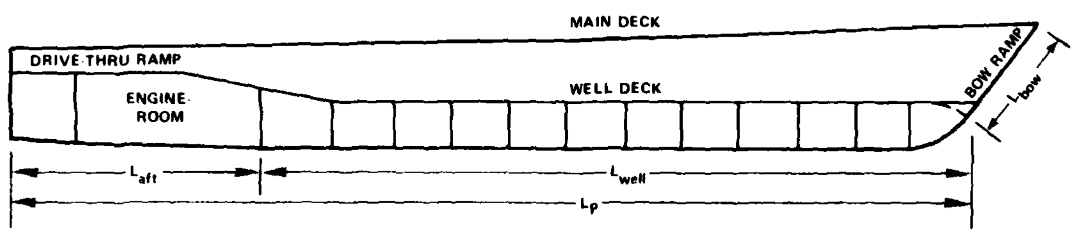


Figure 3 - General Arrangement of Typical Landing Craft

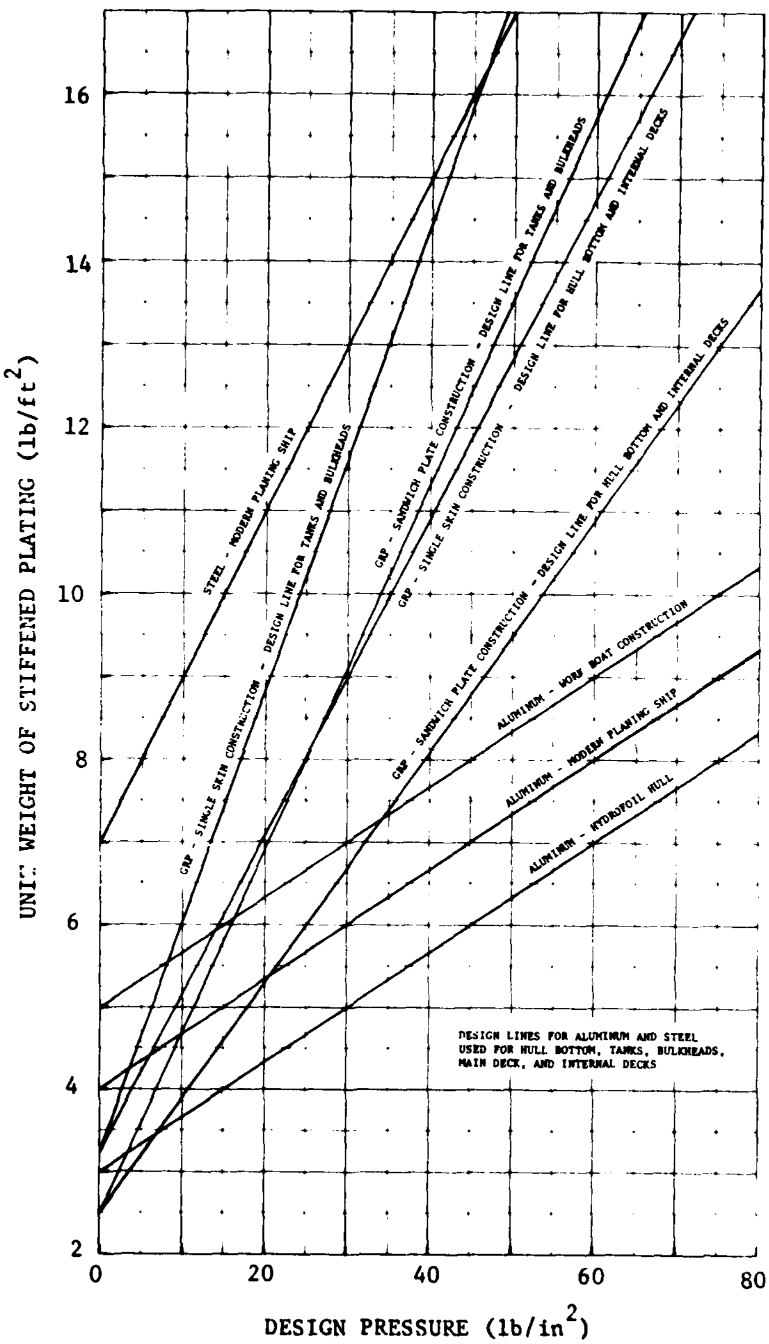


Figure 4 - Weight of Stiffened Plating as Function of Design Load

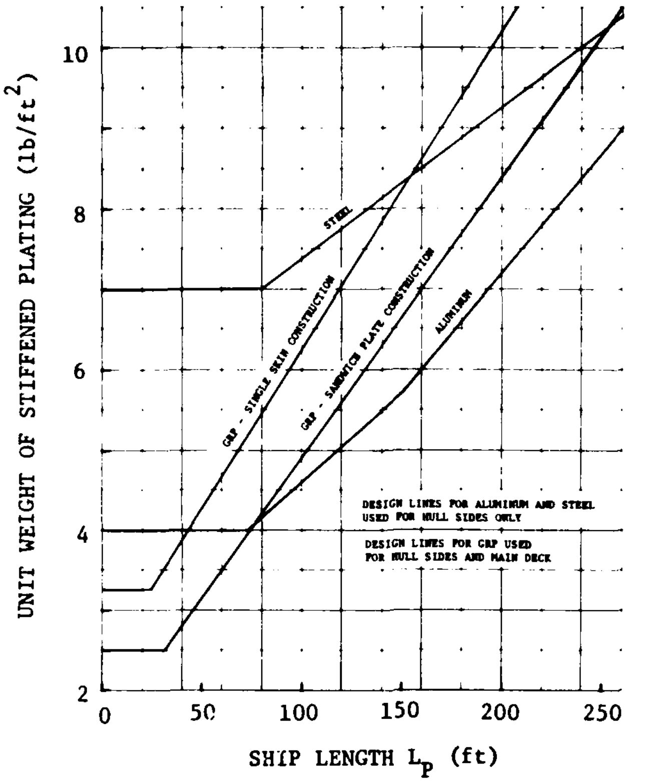


Figure 5 - Weight of Stiffened Plating for Hull Sides

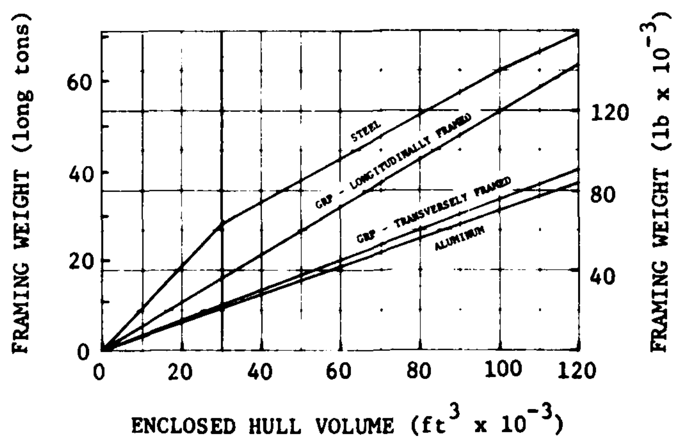


Figure 6 - Hull Framing System Weights

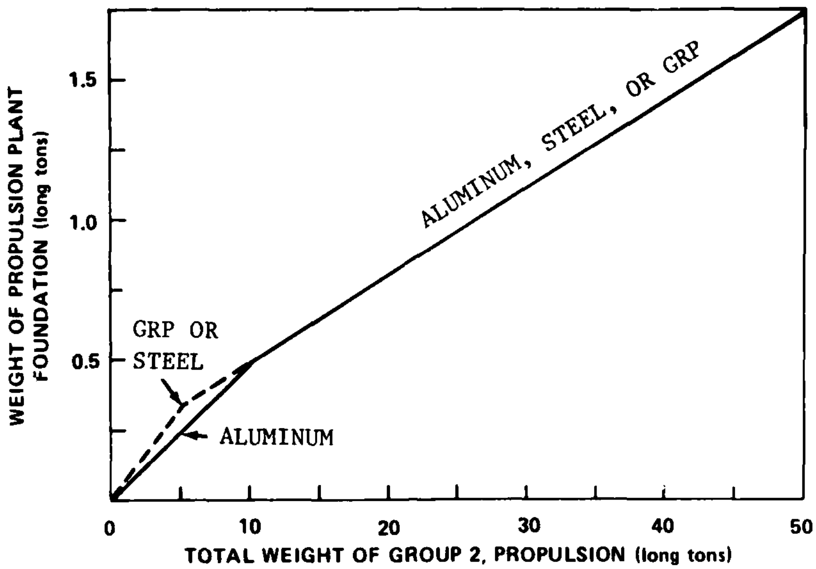


Figure 7 - Propulsion Plant Foundation Weights

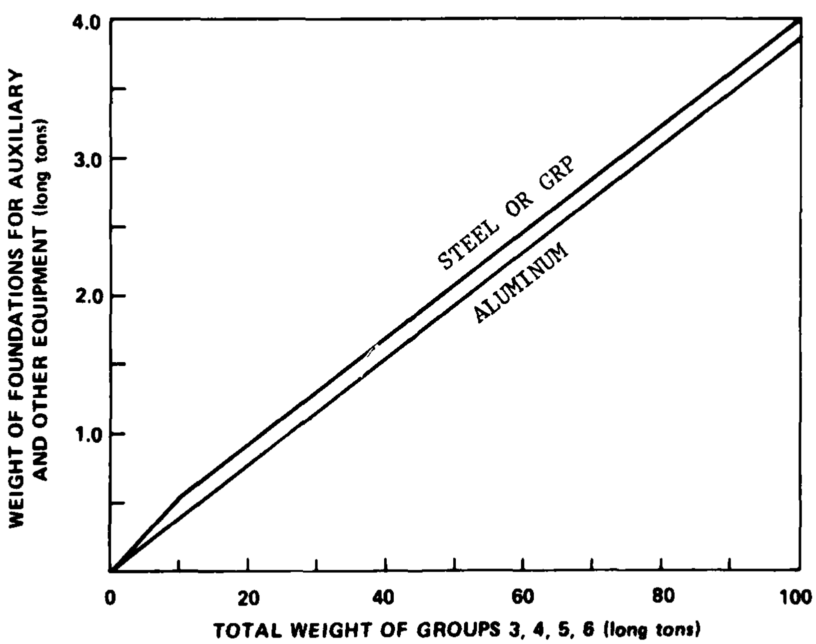


Figure 8 - Auxiliary and Other Equipment Foundation Weights

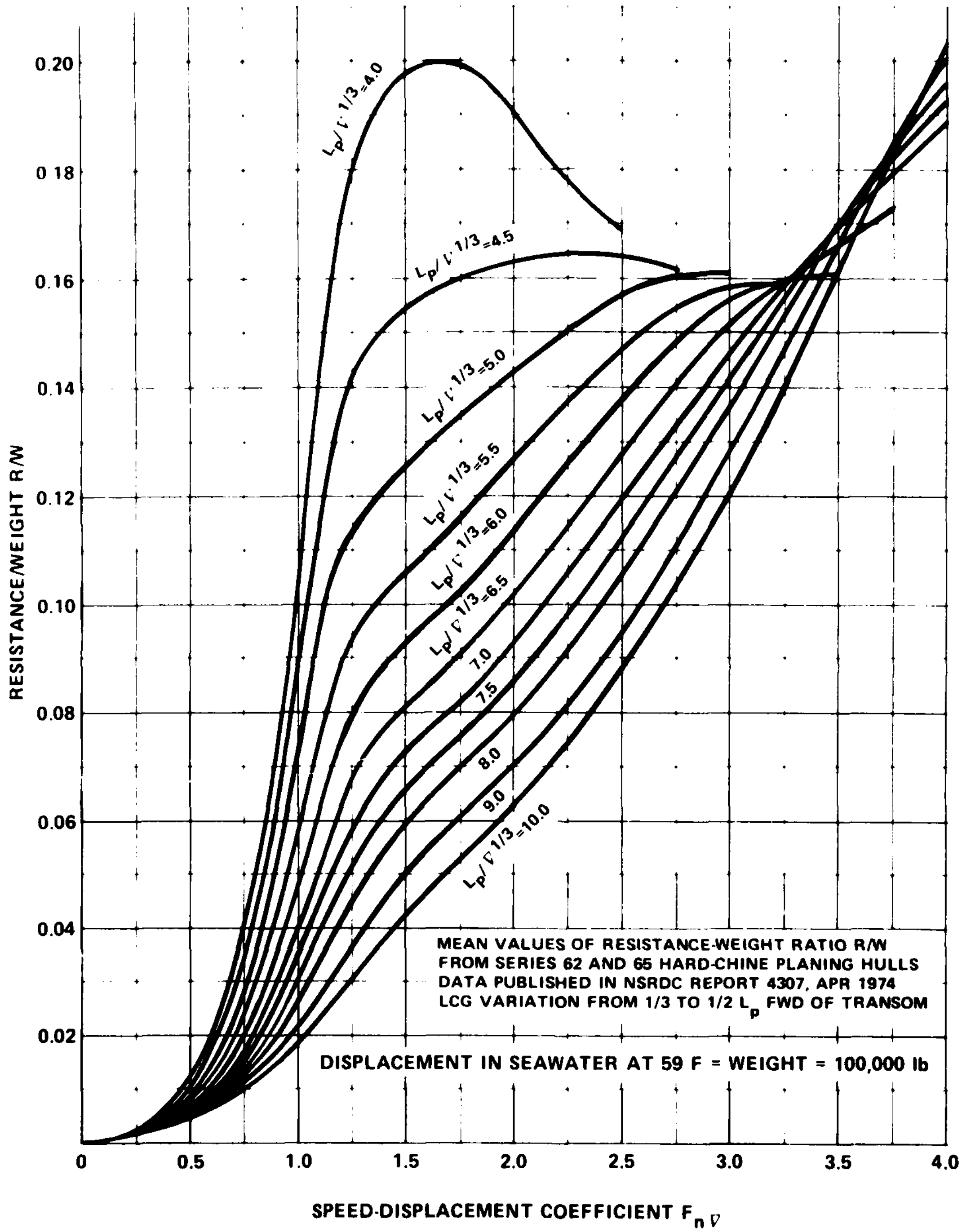


Figure 9 - Mean Values of Resistance/Weight Ratio from Series 62 and 65 Data

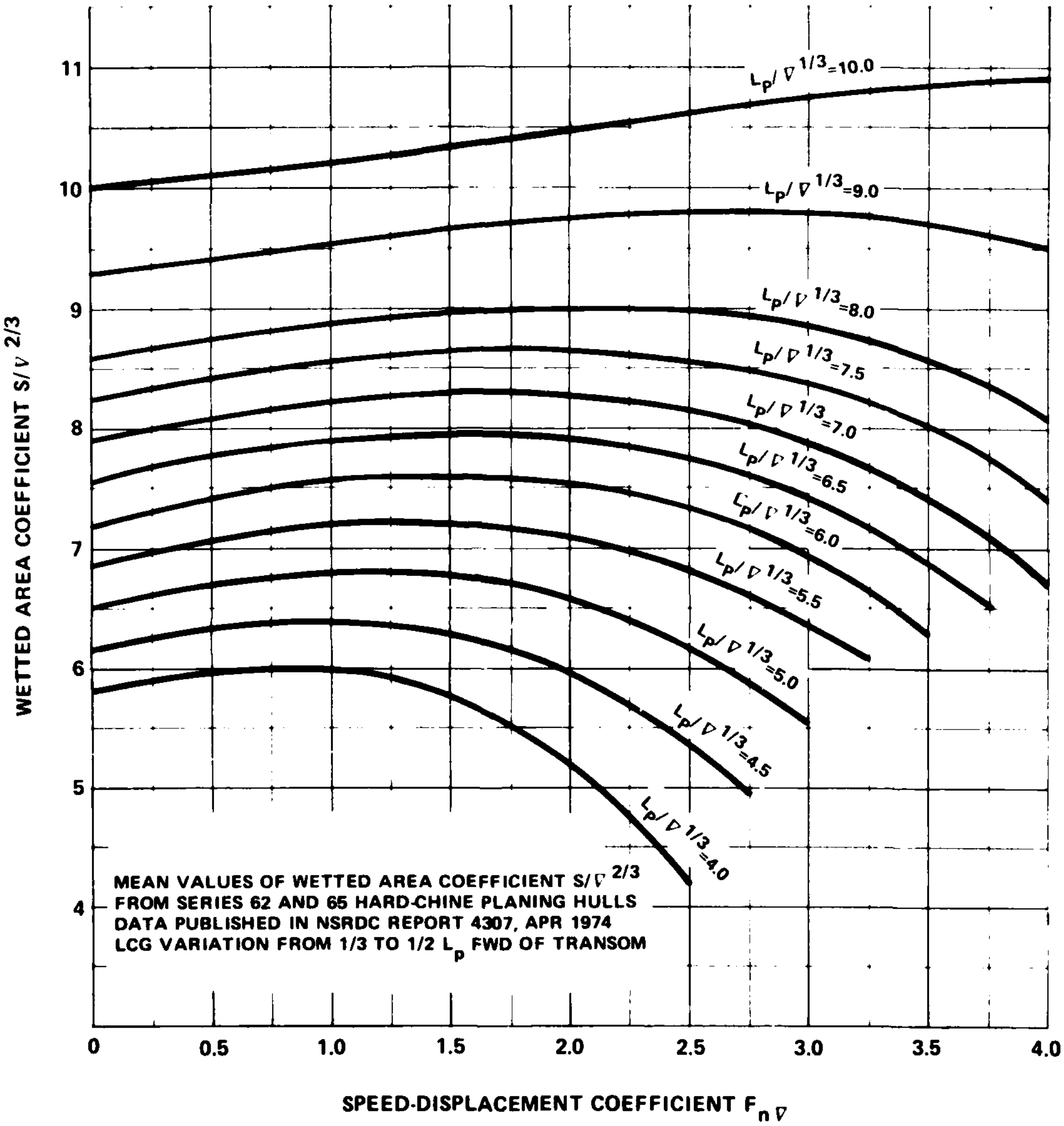


Figure 10 - Mean Values of Wetted Area Coefficient
from Series 62 and 65 Data

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9. Gawn, R.W.L. and L.C. Burrill, "Effect of Cavitation on the Performance of a Series of 16 Inch Model Propellers," Trans. INA, Vol. 99 (1957).

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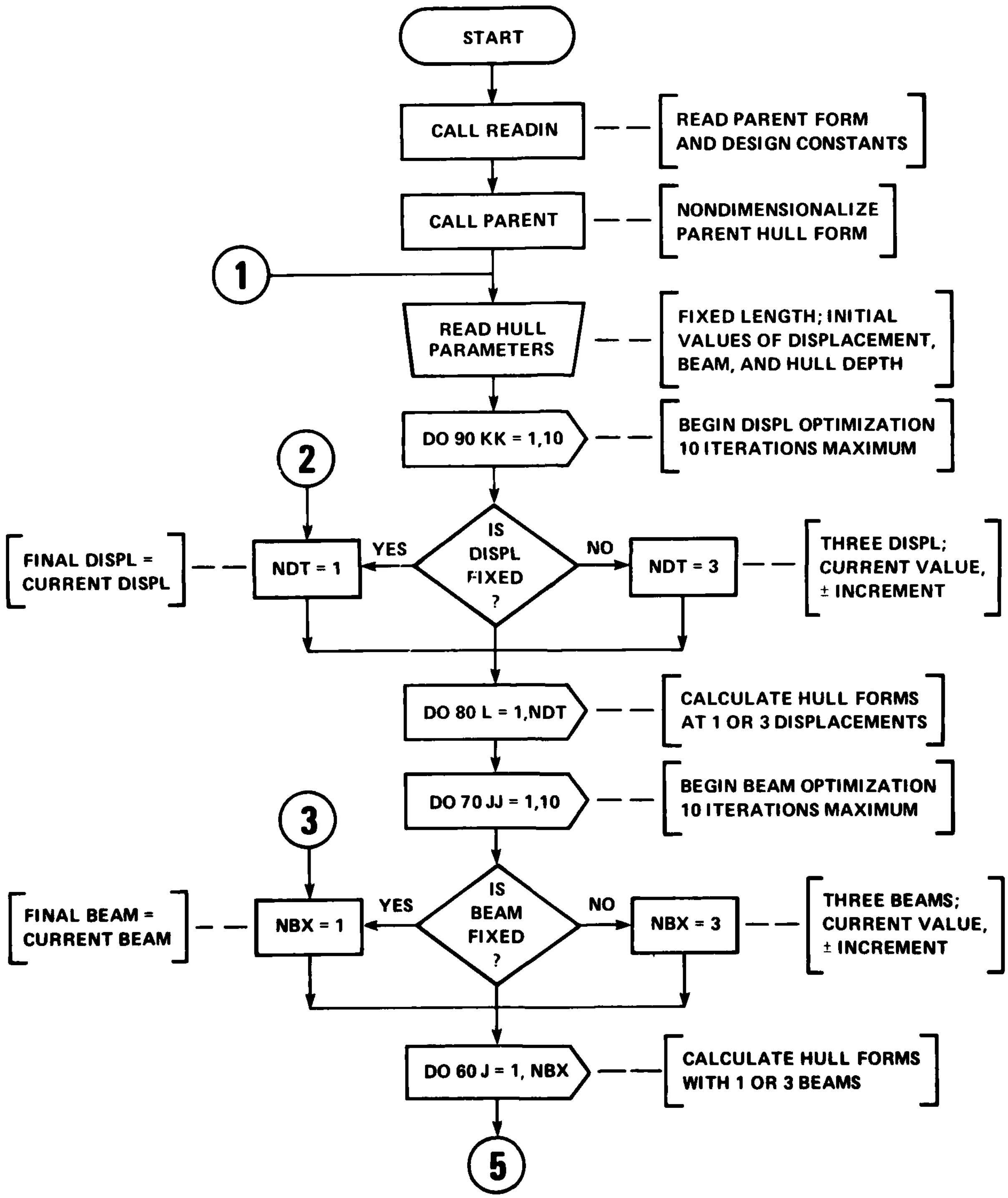
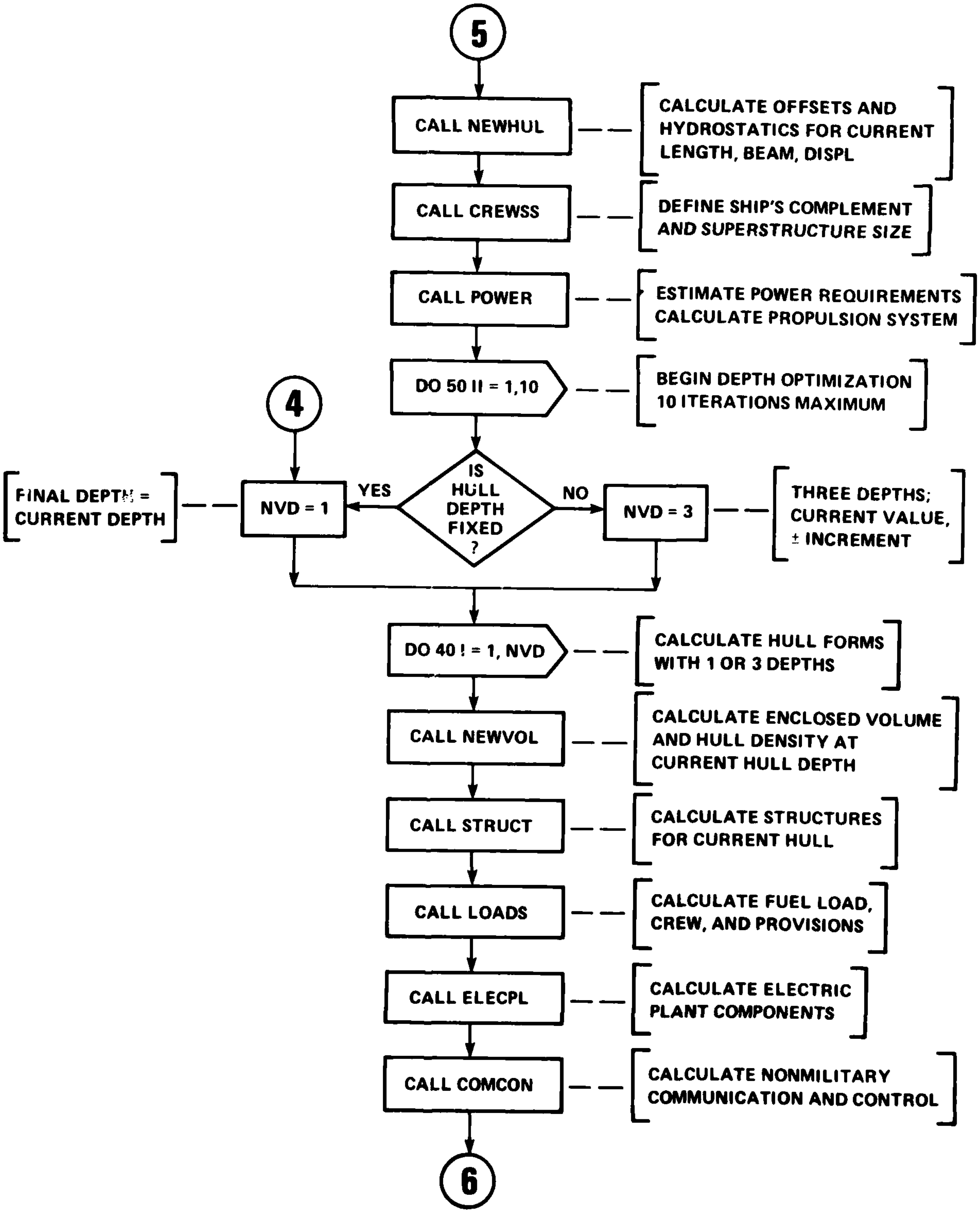
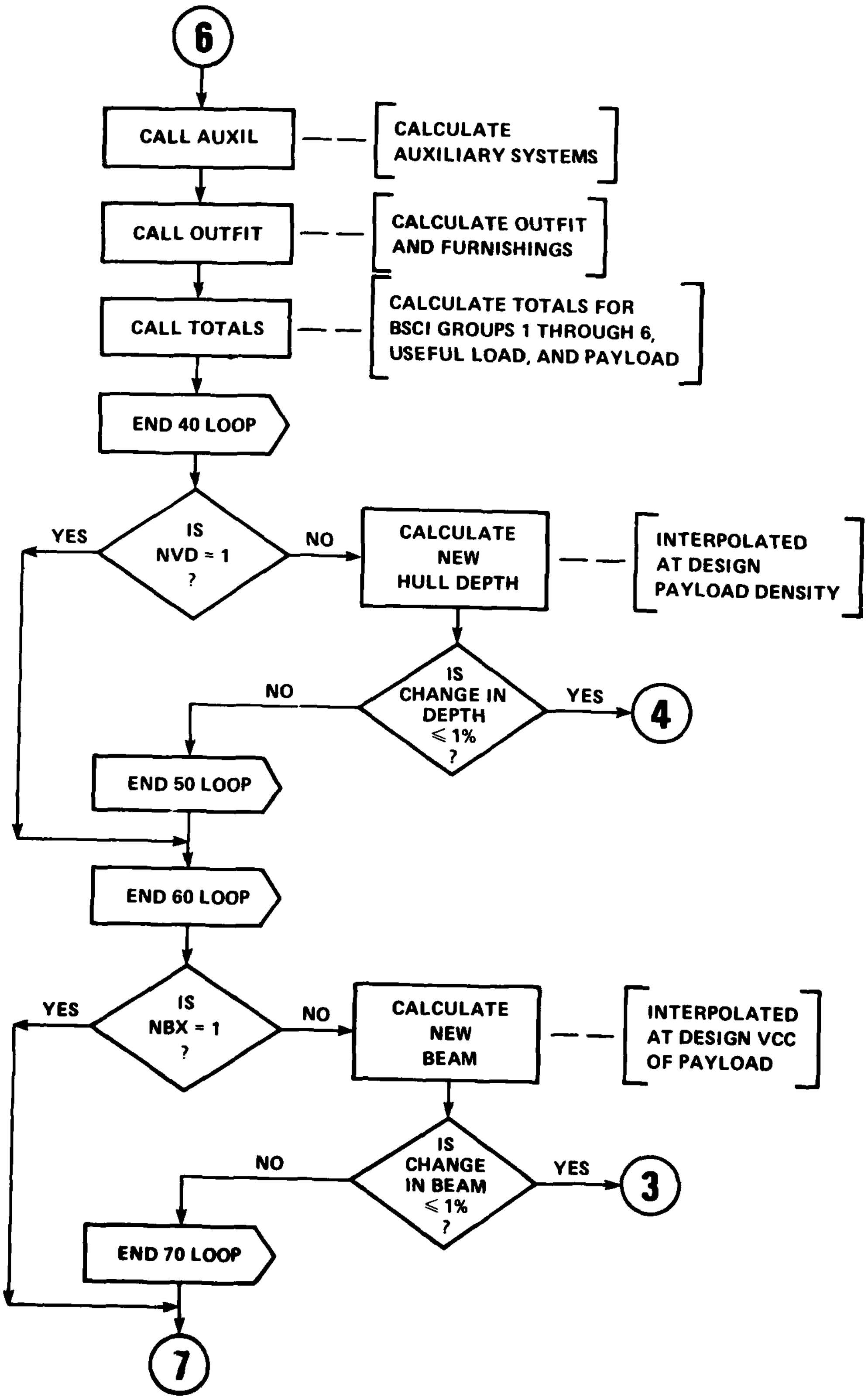
APPENDIX A

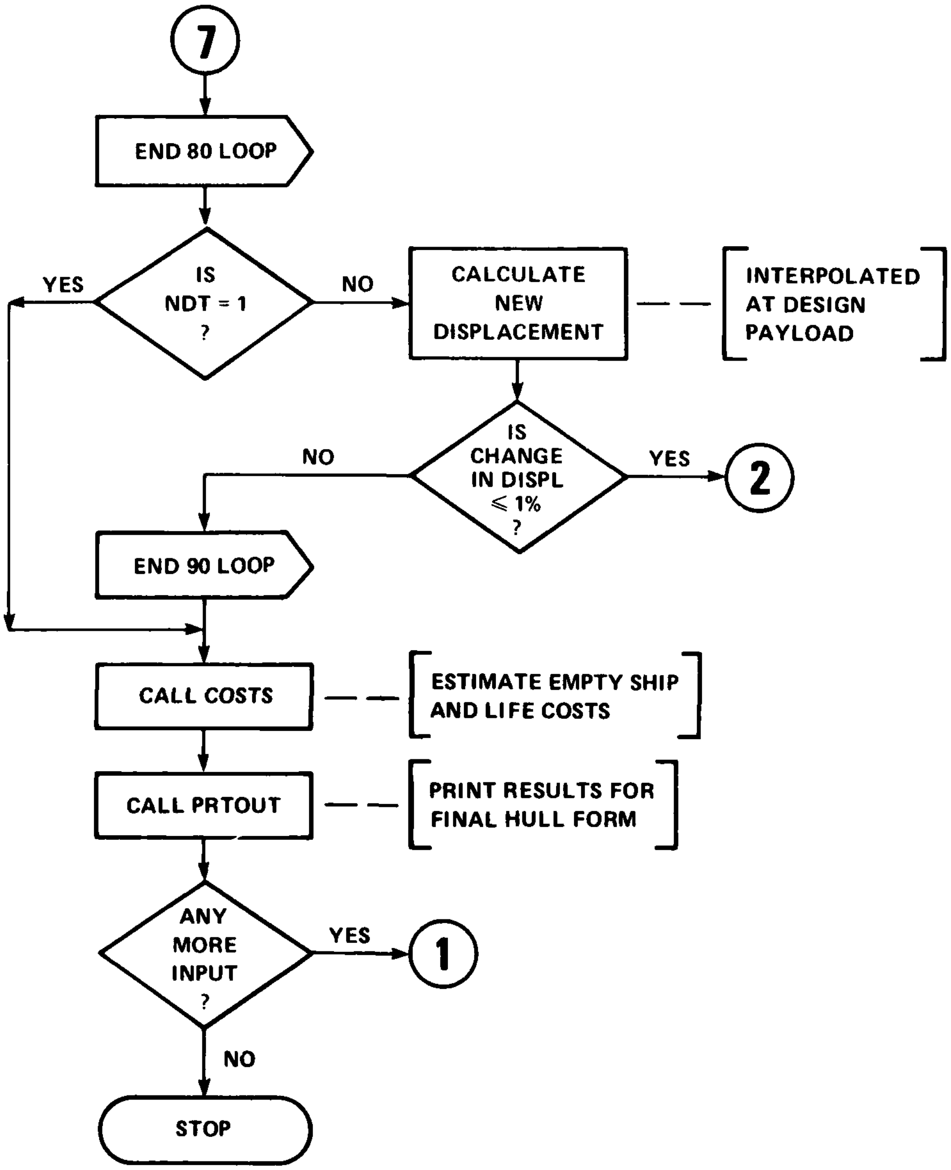
DOCUMENTATION OF SUBPROGRAMS

FLOW CHART OF EXECUTIVE ROUTINE PHFMOPT




5
CALL NEWHUL
CALCULATE OFFSETS AND HYDROSTATICS FOR CURRENT LENGTH, BEAM, DISPL
CALL CREWSS
DEFINE SHIP'S COMPLEMENT AND SUPERSTRUCTURE SIZE
CALL POWER
ESTIMATE POWER REQUIREMENTS CALCULATE PROPULSION SYSTEM
DO 50 II = 1,10
BEGIN DEPTH OPTIMIZATION 10 ITERATIONS MAXIMUM
4
IS HULL DEPTH FIXED ?
YES
NO
NVD = 1
FINAL DEPTH = CURRENT DEPTH
NVD = 3
THREE DEPTHS; CURRENT VALUE, ± INCREMENT
DO 40 I = 1, NVD
CALCULATE HULL FORMS WITH 1 OR 3 DEPTHS
CALL NEWVOL
CALCULATE ENCLOSED VOLUME AND HULL DENSITY AT CURRENT HULL DEPTH
CALL STRUCT
CALCULATE STRUCTURES FOR CURRENT HULL
CALL LOADS
CALCULATE FUEL LOAD, CREW, AND PROVISIONS
CALL ELECPL
CALCULATE ELECTRIC PLANT COMPONENTS
CALL COMCON
CALCULATE NONMILITARY COMMUNICATION AND CONTROL
6


6
CALL AUXIL
CALCULATE AUXILIARY SYSTEMS
CALL OUTFIT
CALCULATE OUTFIT AND FURNISHINGS
CALL TOTALS
CALCULATE TOTALS FOR BSCI GROUPS 1 THROUGH 6, USEFUL LOAD, AND PAYLOAD
END 40 LOOP
IS NVD = 1 ?
YES
NO
CALCULATE NEW HULL DEPTH
INTERPOLATED AT DESIGN PAYLOAD DENSITY
IS CHANGE IN DEPTH ≤ 1% ?
NO
YES
4
END 50 LOOP
END 60 LOOP
IS NBX = 1 ?
YES
NO
CALCULATE NEW BEAM
INTERPOLATED AT DESIGN VCC OF PAYLOAD
IS CHANGE IN BEAM ≤ 1% ?
NO
YES
3
END 70 LOOP
7


7
END 80 LOOP
IS
NDT = 1
?
YES
NO
CALCULATE
NEW
DISPLACEMENT
INTERPOLATED
AT DESIGN
PAYLOAD
IS
CHANGE
IN DISPL
≤ 1%
?
NO
YES
2
END 90 LOOP
CALL COSTS
ESTIMATE EMPTY SHIP
AND LIFE COSTS
CALL PRTOUT
PRINT RESULTS FOR
FINAL HULL FORM
ANY
MORE
INPUT
?
YES
1
NO
STOP

NAME:	PROGRAM PHFMOPT
PURPOSE:	Executive routine for planing hull feasibility model. If hull size is fixed, estimate weight, volume, and vertical center of gravity VCG of major ship components and determine the resultant payload availability. If hull size is to be optimized, vary hull depth, beam, and/or displacement as specified until the design payload requirements are met.
SUBPROGRAMS CALLED:	READIN, PARENT, NEWHUL, CREWSS, POWER, NEWVOL, STRUCT, LOADS, ELECPL, COMCON, AUXIL, OUTFIT, TOTALS, YINTE, COSTS, PRTOUT
INPUT:	Via COMMON blocks and Card Set 29 See Subroutine READIN

IOPT	Control for optimization of displacement Δ_{LT}, maximum beam B_{PX}, and/or hull depth H_h, from Card 6	
PL	L_P	= projected chine length of ship in ft, from Card 29
DTONS	Δ_{LT_o}	= initial value of displacement in long tons,* from Card 29
BPX	B_{PX_o}	= initial value of maximum chine beam in ft, from Card 29
HDM	H_{h_o}	= initial value of hull depth at midships in ft, from Card 29
WPDES	W_P'	= design payload weight in tons, from input Card 9
VPDES	∇_P'	= design payload volume in ft^3, from input Card 9
ZPDES	Z_P'	= VCG of design payload in ft above main deck at midships, from Card 9
DELDT	$d\Delta_{LT}$	= increment of displacement in tons, from Card 28
DELBX	dB_{PX}	= increment of B_{PX} in ft, from Card 28
DELHD	dH_h	= increment of H_h in ft, from Card 28
BXMIN	B_{min}	= minimum value of B_{PX} in ft, from Card 28
BXMAX	B_{max}	= maximum value of B_{PX} in ft, from Card 28

*Weights in long tons will generally be referred to simply as "tons" in this report. 1 ton = 1 long ton = 2240 lb = 0.9842 metric tons

HDMIN	H_{min}	= minimum value of H_h in ft, from Card 28
HDMAX	H_{max}	= maximum value of H_h in ft, from Card 28
OUTPUT:	Via COMMON blocks	
WPLBS	$(W_P)_D$	= design payload weight in lb = 2240 (W_P' in tons)
PLDEN	$(W_P/\nabla_P)_D$	= design payload density in lb/ft^3=$2240W_P'/\nabla_P'$
ZPDES	$(Z_P)_D$	= design payload VCG in ft above main deck = input Z_P'
L	Index for outer DO LOOP L=1,NDT	
J	Index for middle DO LOOP J=1,NBX	
I	Index for inner DO LOOP I=1,NVD	
NDT	Number of displacements calculated in outer loop If IOPT < 3, then NDT = 1, and final $\Delta_{LT} = \Delta_{LT_o}$ Otherwise, NDT = 3, and Δ_{LT} is optimized	
NBX	Number of beams calculated in middle loop If IOPT < 2 or IOPT = 4, then NBX = 1, and final $B_{PX} = B_{PX_o}$ If $B_{PX_o} \leq B_{min}$, then NBX = 1, and final $B_{PX} = B_{min}$ If $B_{PX_o} \geq B_{max}$, then NBX = 1, and final $B_{PX} = B_{max}$ Otherwise, NBX = 3, and B_{PX} is optimized	
NVD	Number of hull depths calculated in inner loop If IOPT < 1 or IOPT > 3, then NVD = 1, and final $H_h = H_{h_o}$ If $H_{h_o} \leq H_{min}$, then NVD = 1, and final $H_h = H_{min}$ If $H_{h_o} \geq H_{max}$, then NVD = 1, and final $H_h = H_{max}$ Otherwise, NVD = 3, and H_h is optimized	
DT(L)	Δ_{LT}	= displacement of current hull
	If NDT = 1, then $\Delta_{LT} = \Delta_{LT_o}$ If NDT = 3, then $\Delta_{LT} = \Delta_{LT_o} - d\Delta_{LT}$, Δ_{LT_o} , $\Delta_{LT_o} + d\Delta_{LT}$	
BX(J)	B_{PX}	= maximum chine beam of current hull
	If NBX = 1, then $B_{PX} = B_{PX_o}$ or B_{min} or B_{max} If NBX = 3, then $B_{PX} = B_{PX_o} - dB_{PX}$, B_{PX_o} , $B_{PX_o} + dB_{PX}$	

HD(I)	H_h	= hull depth at midships of current hull
	If NVD = 1, then $H_h = H_{h_o}$ or H_{min} or H_{max}	
	If NVD = 3, then $H_h = H_{h_o}+dH_h$, H_{h_o} , $H_{h_o}-dH_h$	
PDEN(I)	W_P/∇_P	= payload density of current hull
ZPL(J)	Z_P	= VCG of payload for current hull
WPD(L)	W_P	= weight of payload for current hull
HDM	H_h	= final hull depth in ft
	If NVD = 3, interpolate from the array of W_P/∇_P versus H_h to obtain a new H_{h_o} which approximates the required $(W_P/\nabla_P)_D$. Iterate until the new H_{h_o} agrees with the old H_{h_o} within one percent.	
PDENS	W_P/∇_P	= payload density of final hull
BPX	B_{PX}	= final maximum chine beam in ft
	If NBX = 3, interpolate from the array of Z_P versus B_{PX} to obtain a new B_{PX_o} which approximates the required $(Z_P)_D$. Iterate until the new B_{PX_o} agrees with the old B_{PX_o} within one percent.	
DTONS	Δ_{LT}	= final displacement in tons
	If NDT = 3, interpolate from the array of W_P versus Δ_{LT} to obtain a new Δ_{LT_o} which approximates the required $(W_P)_D$. Iterate until the new Δ_{LT_o} agrees with the old Δ_{LT_o} within one percent.	
	A maximum of 10 iterations is set on each loop. If the initial values of Δ_{LT_o}, B_{PX_o}, and/or H_{h_o} are too far from the design requirements, convergence may be unattainable with this optimization procedure. Therefore, it is well to run a matrix of fixed hulls (IOPT=0) first to aid in the selection of appropriate initial values.	
	See Subroutine PRTOUT for complete output from final hull.	

NAME:	SUBROUTINE READIN		
PURPOSE:	Read input data from punched cards, and echo the input. Store data in COMMON blocks for use by other routines.		
CALLING SEQUENCE:	CALL READIN		
SUBPROGRAMS CALLED:	OWKTQ, CAVKTQ		
DATA REQUIRED:	Via Punched Cards	Card	Columns
PARENT	Identification for hull design	1	1-50
PL	Projected chine length L_P of parent form	2	1-8
BPX	Maximum chine beam B_{PX} of parent form		9-16
DZS	ΔZ_S of parent form, see Figure 1		17-24
NN	Total number of sections input ≤ 27	3	3-4
N	Index of section at $X/L_P = 1.0$		7-8
M	Index of section at $X/L_P = 0.5$		11-12
M40	Index of section at $X/L_P = 0.6$		15-16
M25	Index of section at $X/L_P = 0.75$		19-20
NTB	Number of transverse bulkheads ≤ 15	4	3-4
MTB (1) MTB (2) . . . MTB (NTB)	Indexes of Sections at which transverse bulkheads are located, from transom to bow. Value of NTB must be 9 and values of MTB must be 1, 4, 6, 9, 12, 15, 18, 21, 26 for conventional planing hulls, but may be varied for landing craft		7-8 11-12 . . . .
XLP (I)	Nondimensional longitudinal location of section X/L_P	5(I)	1-8
YC (I)	Half-breadth at chine Y_C		9-16
YS (I)	Half-breadth at main deck Y_S		17-24
ZK (I)	Height of keel above baseline Z_K		25-32
ZC (I)	Height of chine above baseline Z_C		33-40
ZS (I)	Height of main deck $Z_S' - \Delta Z_S = Z_S$		41-48
YK (I)	Half-breadth at keel Y_K		49-56

Format for Card 1 is (5 A 10).
Format for Cards 3, 4, and 6 is (20 I 4).
Format for all other cards is (10 F 8.2).
Data read from each card is immediately echoed, i.e., printed on output page, for use in tracing errors.

		Card	Columns
	Card Set 5 contains NN cards, one for each section, in order from transom to bow. For conventional planing hulls, value of NN must be 27 and sections required are X/L_P = 0, 0.025, 0.05, 0.075, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.875, 0.9, 0.925, 0.95, 0.975, 1.0, and L_{OA}/L_P Values of N, M, M40, M25 are 26, 13, 15, 18. Sections for landing craft are not restricted. Dimensions of offsets on Card Set 5 must be consistent with values on Card 2. The parent form is nondimensionalized before geometric variations are made. The planing hull form is approximated by straight line segments as shown in Figure 1. The general arrangements used for conventional planing hulls and landing craft are shown in Figures 2 and 3, respectively.		
IMAT	Control for hull structural material IMAT = 1 for aluminum hull IMAT = 2 for steel hull IMAT = 3 for GRP single skin hull, with single skin bulkheads* IMAT = 4 for GRP single skin hull, with sandwich plate bulkheads* IMAT = 5 for GRP sandwich plate hull with sandwich plate bulkheads*	6	4

* GRP is glass reinforced plastic, i.e., fiberglass.

		Card	Columns
IOPT	Control for optimization of displacement Δ, maximum beam B_{PX}, and hull depth H_h; length L_p is fixed in each case. IOPT = 0 if Δ, B_{PX}, and H_h are fixed. IOPT = 1 if Δ and B_{PX} are fixed but H_h is varied to meet required payload density W_P/∇_P. IOPT = 2 if Δ is fixed but B_{PX} is varied to meet required VCG of payload Z_P and H_h is varied to meet W_P/∇_P. IOPT = 3 if Δ is varied to meet required payload weight W_P and B_{PX} and H_h are varied to meet Z_P and W_P/∇_P. IOPT = 4 if B_{PX} and H_h are fixed but Δ is varied to meet W_P. IOPT = 5 if H_h is fixed but Δ is varied to meet W_P and B_{PX} is varied to meet Z_P.	6	8
IPRT	Control for printed output IPRT = 0 for minimum output, major weight groups only, one page for each hull IPRT = 1 for complete 4-page output per hull, including BSCI 3-digit level of weight and hull offsets	6	12
IPM	Control for type of engines IPM = 1 for diesel prime movers IPM = 2 for gas turbine prime movers IPM = 3 for CODOG System, gas turbine prime movers with auxiliary diesels IPM = 4 for COGOG System, gas turbine prime movers with auxiliary gas turbines	6	16

		Card	Columns
IPROP	Control for type of thrusters IPROP = 1 for segmental section props (Gawn-Burrill type) IPROP = 2 for Newton-Rader type props (this option not available now) IPROP = 3 for airfoil section propellers (Wageningen B-Screw type) IPROP = 4 for waterjets	6	20
ILC	Control for type of vehicle ILC = 0 for conventional planing hull ILC = 1 for landing craft with well	6	24
	Structural calculations for conventional planing hulls or landing craft are performed by interchangeable subroutines labeled STRUCT. Program users must ensure that the appropriate routine is loaded consistent with values of ILC and IMAT.		
IFT	Control for fuel tanks IFT = 0 if fuel tanks are an integral part of the hull structure IFT = 1 for separate fuel tanks	6	28
IFRM	Control for framing of GRP hulls IFRM = 1 for transverse framing IFRM = 2 for langitudinal framing	6	32
XLWELL	Length of well deck in ft	6A	1-8
XLBOWR	Length of bow ramp in ft		9-16
BWELL	Breadth of well deck in ft		17-24
BBOWR	Breadth of bow ramp in ft		25-32
BAFTR	Breadth of aft (drive-through) ramp in ft		33-40
ZWELL	Height of well deck above baseline in ft		41-48
ZAFTR	Height of aft ramp above baseline in ft		49-56
	See arrangement of landing craft in Figure 3		
* * * * *	Omit Card 6A when ILC = 0 * * * * *		
VDES	Design (maximum) speed V_d in knots	7	1-8
DRANGE	Range at V_d in nautical miles		9-16
	Not required if cruise range is dominant		
H13D	Significant wave height at V_d in ft		17-24
VCRS	Cruise speed V_c in knots $\leq V_d$		25-32
CRANGE	Range at V_c in nautical miles		33-40

		Card	Column
H13C	Significant wave height at V_c in ft	7	41-48
SDF	Standard deviation factor for resistance prediction, if R/W not input. Program uses R/W derived from Series 62 and 65. If SDF=0.0, the mean R/W curves are used; if SDF=1.645, the minimum curves are used. SDF can be varied to approximate the bare hull resistance for a particular hull form.		49-56
DCF	Correlation allowance C_A, generally 0.		57-64
* RWF(1)	Bare hull resistance-weight ratio R/W at design speed		65-72
* RWF(2)	Bare hull R/W at cruise speed		73-80
SPEED(1) SPEED(2) .	Array of 10 speeds, or less, in knots at which power data and accelerations are to be computed	8	1-8
WPDES	Design payload weight W_P' in long tons	9	1-8
VPDES	Design payload volume ∇_P' in ft^3		9-16
ZPDES	VCG of design payload in ft above main deck at midships, positive up		17-24
GM	Required metacentric height $\overline{GM}$ in feet		25-32
CGACC	1/10 highest acceleration criterion at the CG in g's; generally 1.0 or 1.5 g		33-40
* ACC	Total accommodations = CREW + CPO + OFF	10	1-8
* CREW	Number of enlisted personnel		9-16
* CPO	Number of CPO's		17-24
* OFF	Number of officers		25-32
DAYS	Number of days for provisions		33-40
WSFMIN	Minimum unit weight of stiffened plating in lb/ft^2 WSFMIN = 4.0 for medium range aluminum WSFMIN = 7.0 for steel WSFMIN = 3.25 for single skin GRP WSFMIN = 2.5 for sandwich plate GRP	11	1-8
WSLOPE	Slope of stiffened plating curves as function of load WSLOPE = 0.066667 for aluminum WSLOPE = 0.20 for steel WSLOPE = 0.192 for single skin GRP WSLOPE = 0.140 for sandwich plate GRP		9-16

*Parameters preceded by an asterisk will be calculated by program if blank spaces are left on input card.

	Parameter	Description	Card	Columns
	DMAT	Density of structural material in lb/ft^3 DMAT = 166 for aluminum DMAT = 492 for steel DMAT = 103 for GRP	11	17-34
	STRESS	Stress limit in $lb/in.^2$ STRESS = 18000 psi for aluminum STRESS = 30000 psi for steel STRESS = 8000 psi for GRP		25-32
*	FVOLSS	Volume of superstructure in ft^3		33-40
*	FKW	Power of electric plant in KW		41-48
*	PROPNO	Number of propellers or waterjets = number of prime movers	12	1-8
	AUXNO	Number of auxiliary engines, if any		9-16
*	PROPDI	Diameter D of propeller or waterjet impeller in inches		17-24
	PEMAX	Maximum power of each prime mover $P_{e_{max}}$		25-32
	REMAX	Maximum rpm of prime movers $N_{e_{max}}$		33-40
	PD	Propeller pitch-diameter ratio P/D	12	41-48
	EAR	Propeller expanded area ratio EAR		49-56
	Z	Number of blades per propeller		57-64
	TCDES	Value of $\tau_c / \sigma_{0.7R}$ for sizing prop: $\tau_c/\sigma_{0.7R} \approx 0.6$ corresponds to Gawn-Burrill 10% back cavitation criteria; value not required if D is input		65-72
		Card 12A contains input for waterjets only; the design point means maximum input horsepower of pump at design speed of ship		
*	AJET	Area of jet (A_J) in ft^2	12A	1-8
	XKI	Bollard jet velocity/ship speed (K_1) at the design point; $K_1 \approx 2.0$ for peak propulsive efficiency		
	XK2	Constant (K_2) for inlet head recovery (IHR); K_2 = 1.0 for maximum IHR; K_2 = 0.0 for no IHR		17-24

*Parameters preceded by an asterisk will be calculated by program if blank spaces are left on input card.

		Card	Columns
XK3	Constant (K_3) for cavitation criteria where $\tau_c \geq \sigma_{TIP} + 0.14\ K_3$ indicates cavitation; $K_3 = 0.0$ for axial flow; $K_3 \simeq 1.0$ for mixed flow	12A	25-32
DHD	Diameter of impeller hub (D_h)/ impeller diameter (D); typical value of $D_h/D = 0.5$		33-40
TLC	Thrust load coefficient (τ_c) at the design point; not used when A_J is input		41-48
STP	Impeller tip velocity cavitation number (σ_{TIP}) at design point; generally $\sigma_{TIP} \simeq 0.06$ *Note:* If $\sigma_{TIP} = 0.06$ and $K_3 = 1.0$ then $\tau_c \leq \sigma_{TIP} + 0.14\ K_3 = 0.20$ to avoid cavitation		49-56

* * * * *   Omit Card 12A if K ≠ 10   * * * * *

		Card	Columns
FM1	Multiplier for specific weight of prime movers	13	1-8
FM2	Multiplier for specific weight of auxiliary engines		9-16
FM3	Multiplier for specific fuel consumption SFC of prime movers		17-24
FM4	Multiplier for SFC of auxiliary engines		25-32
FM5	Multiplier for rpm of prime movers		33-40
FM6	Multiplier for rpm of auxiliary engines General equations for engines are multiplied by above constants. Use values of 1.0 unless a particular series of engines are required. The general equations may be bypassed with inputs on Card 15.		41-48
GEARC	Constant in gear weight equation GEARC = 16000 for single reduction gears GEARC = 9500 for planetary gears	14	1-8

			Card	Columns
	GEARK	Gear tooth K-factor, generally use 200		9-16
	GEARE	Exponent in gear weight equation GEARE = 0.9 for single reduction gears GEARE = 1.0 for planetary gears		17-24
*	FWE	Weight in lb for each prime mover	15	1-8
*	FWG	Weight in lb of gears for each prime mover		9-16
*	FWEA	Weight in lb of each auxiliary engine		17-24
*	FWGA	Weight in lb of gears for each auxiliary engine		25-32
*	FVOLE	Volume in ft^3 of engine room for prime movers		33-40
*	FVOLE2	Volume in ft^3 of inlets and exhausts for prime movers		41-48
*	FVOLEA	Volume in ft^3 of room for auxiliary engines		49-56
*	FVOLA2	Volume in ft^3 of inlets and exhausts for auxiliary engines		57-64
*	FSFCD	SFC in lb/hp/hr of each prime mover at its full power		65-72
*	FSFCC	SFC in lb/hp/hr of each auxiliary engine at its full power		73-80

Weights and volumes for each BSCI 3-digit group and each load derived from the general equations are multiplied by appropriate K constants on Cards 16 through 25. Constants are generally 1.0, except for special cases. For items not to be included, the constant should be set to 0.

A multiplier of 1.15 for the total of a major (single-digit) group indicates a 15 percent margin which is added to the weight only, not to the volume.

*Parameters preceded by an asterisk will be calculated by program if blank spaces are left on input card.

			Card	Columns
XL(1)	K_U	Multiplier for useful load; K_U must be 1.0	16	1-8
XL(2)	K_F	Multiplier for fuel		9-16
XL(3)	K_{L1}	Multiplier for crew and effects		17-24
XL(4)	K_{L6}	Multiplier for personnel stores		25-32
XL(5)	K_{L12}	Multiplier for potable water		33-40
XL(6)	K_P	Multiplier for payload; K_P must be 1.0		41-48
X1(1)	K_1	Multiplier for total hull structure	17	1-8
X1(2)	K_{100A}	Multiplier for hull bottom		9-16
X1(3)	K_{100B}	Multiplier for hull sides		17-24
X1(4)	K_{101}	Multiplier for framing		25-32
X1(5)	K_{103A}	Multiplier for upper platforms		33-40
X1(6)	K_{103B}	Multiplier for lower platforms		41-48
X1(7)	K_{107}	Multiplier for main deck		49-56
X1(8)	K_{114A}	Multiplier for transverse bulkheads		57-64
X1(9)	K_{114B}	Multiplier for longitudinal bulkheads		65-72
X1(10)	K_{111}	Multiplier for superstructure		73-80
X1(11)	K_{112}	Multiplier for propulsion plant foundations	18	1-8
X1(12)	K_{113}	Multiplier for other foundations		9-16
X1(13)	K_{att}	Multiplier for attachments		17-24
X2(1)	K_2	Multiplier for total propulsion	19	1-8
X2(2)	K_{201}	Multiplier for propulsion units		9-16
X2(3)	K_{203}	Multiplier for shafting, bearings, propellers		17-24
X2(4)	$K_{204, 205}$	Multiplier for combustion air supply, uptakes		25-32

			SUBROUTINE READIN Card	Columns
X2(5)	K_{206}	Multiplier for propulsion control equipment		33-40
X2(6)	K_{208}	Multiplier for circulating and cooling water system		41-48
X2(7)	K_{210}	Multiplier for fuel oil service system		49-56
X2(8)	K_{211}	Multiplier for lubricating oil system		57-64
X2(9)	$K_{250,251}$	Multiplier for repair parts, and operating fluids		65-72
X3(1)	K_3	Multiplier for total electric plant	20	1-8
X3(2)	K_{300}	Multiplier for electric power generation		9-16
X3(3)	K_{301}	Multiplier for power distribution switchboard		17-24
X3(4)	K_{302}	Multiplier for power distribution system cables		25-32
X3(5)	K_{303}	Multiplier for lighting system		33-40
X4(1)	K_4	Multiplier for total nonmilitary communication and control	21	1-8
X4(2)	K_{400}	Multiplier for nonelectronic navigation equipment		9-16
X4(3)	K_{401}	Multiplier for interior communication system		17-24
X5(1)	K_5	Multiplier for total auxiliary system	22	1-8
X5(2)	$K_{500,502}$	Multiplier for heating, air conditioning		9-16
X5(3)	K_{501}	Multiplier for ventilation system		17-24
X5(4)	K_{503}	Multiplier for refrigerating spaces		25-32
X5(5)	K_{505}	Multiplier for plumbing installations		33-40

			Card	Columns
X5(6)	K_{506}	Multiplier for firemain, flushing, sprinkling		41-48
X5(7)	K_{507}	Multiplier for fire extinguishing system		49-56
X5(8)	K_{508}	Multiplier for drainage and ballast		57-64
X5(9)	K_{509}	Multiplier for fresh water system		65-72
X5(10)	K_{510}	Multiplier for scuppers and deck drains		73-80
X5(11)	K_{511}	Multiplier for fuel and diesel oil filling	23	1-8
X5(12)	K_{513}	Multiplier for compressed air system		9-16
X5(13)	K_{517}	Multiplier for distilling plant		17-24
X5(14)	K_{518}	Multiplier for steering systems		25-32
X5(15)	K_{519}	Multiplier for rudders		33-40
X5(16)	K_{520}	Multiplier for mooring, anchor, deck machinery		41-48
X5(17)	K_{521}	Multiplier for stores handling		49-56
X5(18)	K_{528}	Multiplier for replenishment at sea		57-64
X5(19)	K_{550}	Multiplier for repair parts		65-72
X5(20)	K_{551}	Multiplier for operating fluids		73-80
X6(1)	K_6	Multiplier for total outfit and furnishing	24	1-8
X6(2)	K_{600}	Multiplier for hull fittings		9-16
X6(3)	K_{601}	Multiplier for boats, stowages, handling		17-24
X6(4)	K_{602}	Multiplier for rigging and canvas		25-32
X6(5)	K_{603}	Multiplier for ladders and grating		33-40

			Card	Columns
X6(6)	K_{604}	Multiplier for nonstructural bulkheads		41-48
X6(7)	K_{605}	Multiplier for painting		49-56
X6(8)	K_{606}	Multiplier for deck covering		57-64
X6(9)	K_{607}	Multiplier for hull insulation		65-72
X6(10)	K_{608}	Multiplier for storerooms, stowage, lockers		73-80
X6(11)	K_{609}	Multiplier for equipment for utility spaces	25	1-8
X6(12)	K_{610}	Multiplier for workshops		9-16
X6(13)	K_{611}	Multiplier for galley, pantry, commissary		17-24
X6(14)	K_{612}	Multiplier for living spaces		25-32
X6(15)	K_{613}	Multiplier for offices, control center		33-40
X6(16)	K_{614}	Multiplier for medical-dental spaces		41-48
CKN(1)	Cost factor for hull structures CKN(1) = 2.191 for conventional aluminum hull CKN(1) = 1.000 for conventional steel hull		26	1-8
CKN(2)	Cost factor for propulsion CKN(2) = 1.000 for most cases Program makes adjustment to general equations in case of diesel prime movers and/or waterjets			9-16
CKN(3)	Cost factor for electric plant CKN(3) = 2.036 for most cases			17-24
CKN(4)	Cost factor for communication and control CKN(4) = 1.000 for most cases			25-32
CKN(5)	Cost factor for auxiliary systems CKN(5) = 1.528 for most cases			33-40
CKN(6)	Cost factor for outfit and furnishing CKN(6) = 1.000 for most cases			41-48
CKN(7)	Cost factor for payload CKN(7) = 1.000 for most cases			49-56

		Card	Columns
OPHRS	Operating hours per month	27	1-8
OPYRS	Total vehicle operating years, @ 15		9-16
XUNITS	Number of vehicles to be built		17-24
TIMED	Portion of time operating at maximum speed		25-32
TIMEC	Portion of time operating at cruise speed		33-40
FUELR	Cost of fuel per ton in dollars		41-48
	Note: TIMED + TIMEC = 1.0		
DELDT	Increment of displacement in tons for optimization routine if IOPT = 3	28	1-8
DELBX	Increment of max beam B_{PX} in ft for optimization routine if IOPT > 1		9-16
DELHD	Increment of hull depth H_h in ft for optimization routine if IOPT > 0		17-24
BXMIN	Minimum value of B_{PX} in ft If not restricted, make BXMIN = 0		25-32
BXMAX	Maximum value of B_{PX} in ft If not restricted, make BXMAX very large		33-40
HDMIN	Minimum value of H_h in ft If not restricted, make HDMIN = 0		41-48
HDMAX	Maximum value of H_h in ft If not restricted, make HDMAX very large		49-56
PL	Ship projected chine length L_p in ft	29	1-8
DTONS	Initial value of displacement Δ_{LT} in long tons		9-16
BPX	Initial value of beam B_{PX} in ft		17-24
HDM	Initial value of hull depth H_h in ft		25-32
* A1=RWF(1)	Bare hull R/W at design speed		33-40
* A2=RWF(2)	Bare hull R/W at cruise speed		41-48
* A3=FVOLSS	Volume of superstructure in ft^3		49-56

Card Set 29 is actually read by the main routine PHFMOPT, but is included here for convenience. One card is read for each hull variation desired. Blank card is inserted at end to terminate program.

* Optional parameters to supersede corresponding values on Cards 7 and 11.

CONSTANTS:	Set by DATA statements
RHO	Water density ρ in lb $\times$ sec^2/ft^4 ρ = 1.9905 for sea water at 59 F
VIS	Kinematic viscosity of water ν in ft^2/sec $\nu = 1.2817 \times 10^{-5}$ for sea water at 59 F
GA	Acceleration of gravity g in ft/sec^2 g = 32.174 at 45 deg north latitude
RHO2	$\rho/2$
RG	Density in lb/ft^3 = ρ g
TON	Pounds per ton = 2240
DPR	Multiplier to convert degrees to radians = 57.29578
RPD	Multiplier to convert radians to degrees = 0.01745329
ZERO	0.0
HALF	1./2.
TWO	2.0
FOUR	4.0
EIGHT	8.0
TWELVE	12.0
THIRD	1./3.
THIRD2	2./3.
NL	6 = dimension of arrays for loads
N1	14 = dimension of arrays for structures, Group 1
N2	10 = dimension of arrays for propulsion, Group 2
N3	6 = dimension of arrays for electric plant, Group 3
N4	4 = dimension of arrays for communication and control, Group 4
N5	21 = dimension of arrays for auxiliary systems, Group 5
N6	17 = dimension of arrays for outfit and furnishings, Group 6

First item in each array is total for the group.
Last item in each array, except loads, is the margin.
Intermediate Items are BSCI 3-digit groupings.

L0	Array of numerical identification for loads
L1 L2 L3 L4 L5 L6	Arrays of numerical identification for items in Groups 1, 2, 3, 4, 5, 6 respectively, corresponding to BSCI codes in most cases. The margins are arbitrarily appended with 99.

NAME: SUBROUTINE PRTOUT

PURPOSE: Print out weights, volumes, VCG's and other pertinent data for fixed-size hull (IOPT=0) or optimized hull (IOPT>0)

CALLING SEQUENCE: CALL PRTOUT

SUBPROGRAMS CALLED: PRCOEF, PHRES, SAVIT, PRINTP, SIMPUN, YINTX

INPUT: Via COMMON blocks

Data for ship of length L_p from Program PHFMOPT

If hull depth, beam, and/or displacement has been optimized (IOPT>0), only the results of the final hull is printed.

OUTPUT: Via 132-Column printed pages

PAGE 1 - Minimum Printout				Subroutines where defined
1.	DTONS	Δ_{LT}	= ship displacement in long tons	PHFMOPT
	PTITLE	Identification for propeller series or waterjets		READIN
	TPARENT	Identification for hull design		READIN
2.	SLR	$L_p/\nabla^{1/3}$	= slenderness ratio	NEWHUL
	RLB	L/B	= length-beam ratio L_p/B_{PX}	NEWHUL
	APV	$A_p/\nabla^{2/3}$	= loading coefficient	NEWHUL
	PL	L_p	= ship projected chine length in ft	PHFMOPT
	BPX	B_{PX}	= maximum chine beam in ft	PHFMOPT
	BPA	B_{PA}	= average chine beam in ft	NEWHUL
	HM	T	= draft at midships in ft	NEWHUL
	HT	T_t	= draft at transom in ft	NEWHUL
	DIN	Diameter of propeller in inches, or diameter of waterjet impeller, inches		PROPS WJETS

The following are printed for propellers:

	PD	P/D	= propeller pitch ratio	READIN
	EAR	EAR	= expanded area ratio	READIN
	NPR	n_{pr}	= number of propellers	READIN
	EE	ϵ	= shaft angle in degrees	PROPS
	SHL	L_{sh}	= shaft length in ft	PROPS
	SHDO	d_o	= outer diameter of shaft in inches	POWER

Numbers 1., 2., indicate beginning of new line.

The following are printed for waterjets:

			Subroutines where defined
AJET	A_J	= area of jet in ft^2	WJETS
XK1	K_1	= bollard jet velocity/ship speed at design point	READIN
XK2	K_2	= constant for inlet head recovery	READIN
XK3	K_3	= constant for τ_c vs σ_{TIP} cavitation criteria	READIN
DHD	D_h/D	= diameter of impeller hub/ diameter of impeller	READIN
TLC	τ_{c_d}	= thrust load coefficient at design point	READIN
STIP	σ_{TIP_d}	= impeller tip velocity cavitation number at design point	READIN
IOPT	Control parameter for optimization		READIN
3. DLBS	Δ	= ship displacement in lb	NEWHUL
DAYS	Days for provisions		READIN
OFF	Number of officers		READIN or CREWSS
CPO	Number of CPO's		READIN or CREWSS
CREW	Number of enlisted men		READIN or CREWSS
ACC	Total accommodations		READIN or CREWSS
GM	$\overline{GM}$	= metacentric height in ft	READIN
KM	$\overline{KM}$	= baseline to metacenter in ft	NEWHUL
KG	$\overline{KG}$	= net VCG of ship in ft = $\overline{KM} - \overline{GM}$	NEWHUL
XCG	LCG/L_p	= longitudinal center of gravity forward of transom / ship length	NEWHUL
VOLH	∇_h	= hull volume, up to main deck, in ft^3	NEWVOL

				Subroutines where defined
	VOLSS	V_{ss}	= volume enclosed by superstructure in ft^3	CREWSS
	NTB	n_{tb}	= number of transverse bulkheads	STRUCT
	IFRM	IFRM	= 1 or 2 for transversely or longitudinally framed GRP hull	READIN
4.	MAT	Structural material: Aluminum IMAT = 1 Steel IMAT = 2 GRP(A-A) IMAT = 3 GRP(A-B) IMAT = 4 GRP(B-B) IMAT = 5 A indicates single skin GRP B indicates sandwich plate GRP 1st letter refers to the hull 2nd letter refers to the bulkheads		READIN
	WSFMIN	S_{min}	= minimum unit weight of plating in lb/ft^2	READIN
	WSLOPE	S_P	= slope of unit weight curve, Figure 4	READIN
	DMAT	γ_{mat}	= density of structural material in lb/ft^3	READIN
	STRESS	σ_{limit}	= stress limit of material in $lb/in.^2$	READIN
	TAU(1) TAU(2)	τ	= trim angles at design speed and cruise speed in degrees	SAVIT
	RWS(1) RWS(2)	$(R/W)_s$	= resistance-weight ratios at design speed and cruise speed from Savitsky equations	SAVIT
	CLOAD	C_Δ	= beam loading coefficient $= \Delta/(\rho\ g\ B_{PX}^3) = \nabla/B_{PX}^3$	PRTOUT

			Subroutines where defined
H13X	Variable not used in current program		
RANCED	Range at design speed in nautical miles		POWER
RANGEC	Range at cruise speed in nautical miles		POWER
5a. VKT(1)	V_d	= design (max) speed in knots	POWER
FNV(1)	$F_{n\nabla}$	= speed-displacement coefficient	POWER
SIG(1)	σ	= propeller cavitation number or waterjet cavitation no. based on inlet velocity	PROPS WJETS
H13(1)	$H_{1/3}$	= significant wave height in ft specified for design speed	POWER
RWB(1)	$(R/W)_b$	= resistance-weight ratio of bare hull	POWER
RWA(1)	$(R/W)_a$	= resistance-weight ratio of appendaged hull	POWER
RWW(1)	$(R/W)_w$	= resistance-weight ratio of appendaged hull in seaway at wave height $H_{1/3}$	POWER

The following are printed for propellers:

TWF(1)	1-w	= thrust wake factor = torque wake factor	POWER
TDF(1)	1-t	= thrust deduction factor	POWER
THLD(1)	K_T/J^2	= thrust loading coefficient	POWER
TJ(1)	J	= propeller advance coefficient	PRINTP
EP(1)	η_0	= propeller efficiency	PRINTP
PC(1)	η_D	= propulsive coefficient	PROPS

The following are printed for waterjets:

TWF(1)	1-w	= wake factor = 1.0	POWER
TDF(1)	1-t	= thrust deduction factor	POWER
XJ(1)	J'	= effective advance coefficient	WJETS

Notes: The letter C printed to the right of K_T/J^2 indicates that the Gawn-Burrill 10% back cavitation criteria is exceeded.
A star * printed to the right of K_T/J^2 indicates thrust limit due to cavitation.
A star * printed to the right of η_0 indicates that the propeller is operating at a J greater than maximum efficiency.

			Subroutines where defined
QC(1)	Q'	= mass flow in gal/min x 10^{-3}	WJETS
SS(1)	S_s	= suction specific speed x 10^{-3}	WJETS
TCD	$\tau_{max}-\tau_c$	= (maximum thrust load coefficient at cavitation point) - (actual thrust load coefficient); negative value indicates cavitation	WJETS

The following are printed for either propellers or waterjets:

PCO(1)	OPC	= overall performance coefficient	POWER
THRUST(1)	T	= total thrust requirement in lb	POWER
TORQUE(1)	Q	= total torque in shafts in ft-lb	POWER
RPM(1)	N	= speed of propellers or waterjets in rpm	PROPS or WJETS
EHP(1)	P_E	= total effective power	POWER
DHP(1)	P_D	= total power delivered at propellers or waterjets	PROPS or WJETS
BHP(1)	P_B	= total brake power	POWER
5b. VKT(2)	V_c	= cruise speed in knots	POWER

Line 5b contains parameters for cruise speed in same order as line 5a for design speed. Line 5b not printed if cruise speed same as design.

6a. SPEED(I)	V_K	= speed in knots	READIN

6b.
.
.

Lines 6a, 6b, etc. contain same parameters as lines 5 for array of speeds input on Card 8.

7. VMAX	V_{max}	= maximum speed in knots	PRTOUT

Line 7 contains same parameters as lines 5 & 6 for speed attainable at maximum power.

			Subroutines where defined
8a.	PMTIT	Type of prime movers	PRTOUT
	VDES	V_d = design (maximum) speed in knots	READIN
	PRN	n_{pr} = number of prime movers	POWER
	PE	P_e = maximum horsepower of each prime mover	POWER
	RE	N_e = speed of prime movers in rpm	POWER
	SFCD	SFC_d = specific fuel comsumption of prime movers at design speed in lb/hp/hr	POWER
	RANGED	Range in nautical miles at design speed on prime movers with full fuel load	POWER
	SWE	SW_e = specific weight of prime movers in lb/hp	POWER
	WE	W_e = weight of each prime mover in lb	POWER
	GR	m_g = gear ratio for prime movers	POWER
	WG	W_g = weight of gears for each prime mover in lb	POWER
	WPR	W_{pr} = weight of each propeller or waterjet in lb	POWER
	WSH	W_{sh} = weight of each propeller shaft in lb	POWER
	WB	W_b = weight of couplings, bearings, etc. for each shaft in lb	POWER
	GEARC GEARK GEARE	Gear constants from input Card 14	READIN READIN READIN
8b.	VCRS	V_c = cruise speed in knots	READIN
	AUXNO	n_{aux} = number of auxiliary engines, if any	READIN

				Subroutines where defined
	PEA	P_a	= maximum horsepower of each auxiliary engine	POWER
	REA	N_a	= speed of auxiliary engine in rpm	POWER
	SFCC	SFC_c	= specific fuel consumption at cruise speed in lb/hp/hr	POWER
	RANGEC	Range in nautical miles at cruise speed with full fuel load		POWER
	SWA	SW_a	= specific weight of auxiliary engines in lb/hp	POWER
	WEA	W_a	= weight of each auxiliary engine in lb	POWER
	GRA	m_{g_a}	= gear ratio for auxiliary engines	POWER
	WGA	W_{g_a}	= weight of gears for each auxiliary engine in lb	POWER
		If there are no auxiliary engines, only V_c, SFC_c, and $Range_c$ are printed on line 8b and SFC_c and $Range_c$ apply to the prime movers operating at cruise speed		
9.	WPLBS	$(W_P)_D$	= design payload weight in lb	PHFMOPT
	VPDES	$(\nabla_P)_D$	= design payload volume in ft^3	READIN
	ZPDES	$(Z_P)_D$	= design payload VCG	READIN
	PLDEN	$(W_P/\nabla_P)_D$	= design payload density in lb/ft^3	PHFMOPT
10.	VDENS	Δ/∇_h	= vehicle density in lb/ft^3	NEWVOL

				Subroutines where defined
11.	PDENS	W_P/∇_P	= payload density in lb/ft^3; should agree with $(W_P/\nabla_P)_D$ within one percent if IOPT = 1, 2, or 3.	PHFMOPT
12.	DLBS	Δ	= displacement (total weight) in lb	NEWHUL
	R(1)	W_1/W_T	= Group 1 weight fraction	TOTALS
	R(2)	W_2/W_T	= Group 2 weight fraction	TOTALS
	R(3)	W_3/W_T	= Group 3 weight fraction	TOTALS
	R(4)	W_4/W_T	= Group 4 weight fraction	TOTALS
	R(5)	W_5/W_T	= Group 5 weight fraction	TOTALS
	R(6)	W_6/W_T	= Group 6 weight fraction	TOTALS
	R(7)	W_E/W_T	= Empty ship weight fraction	TOTALS
	R(8)	W_U/W_T	= Useful load weight fraction	TOTALS
	R(9)	W_{CE}/W_T	= Crew and provisions weight fraction	TOTALS
	R(10)	W_F/W_T	= Fuel weight fraction	TOTALS
	R(11)	W_P/W_T	= Payload weight fraction	TOTALS
13.	HDM	H_h	= hull depth at midships in ft	
	G(1)	Z_1	= Group 1 VCG / hull depth	TOTALS
	G(2)	Z_2	= Group 2 VCG / hull depth	TOTALS
	G(3)	Z_3	= Group 3 VCG / hull depth	TOTALS
	G(4)	Z_4	= Group 4 VCG / hull depth	TOTALS
	G(5)	Z_5	= Group 5 VCG / hull depth	TOTALS
	G(6)	Z_6	= Group 6 VCG / hull depth	TOTALS
	G(7)	Z_E	= Empty ship VCG / hull depth	TOTALS
	G(8)	Z_U	= Useful load VCG / hull depth	TOTALS

				Subroutines where defined
	G(9)	Z_{CE}	= Crew and provisions VCG / hull depth	TOTALS
	G(10)	Z_F	= Fuel VCG / hull depth	TOTALS
	G(11)	Z_P	= Payload VCG / hull depth	TOTALS
14.	VOLT	∇_T	= total volume, including superstructure, in ft^3	NEWVOL
	S(1)	∇_1/∇_T	= Group 1 volume fraction	TOTALS
	S(2)	∇_2/∇_T	= Group 2 volume fraction	TOTALS
	S(3)	∇_3/∇_T	= Group 3 volume fraction	TOTALS
	S(4)	∇_4/∇_T	= Group 4 volume fraction	TOTALS
	S(5)	∇_5/∇_T	= Group 5 volume fraction	TOTALS
	S(6)	∇_6/∇_T	= Group 6 volume fraction	TOTALS
	S(7)	∇_E/∇_T	= Empty ship volume fraction	TOTALS
	S(8)	∇_U/∇_T	= Useful load volume fraction	TOTALS
	S(9)	∇_{CE}/∇_T	= Crew and provisions volume fraction	TOTALS
	S(10)	∇_F/∇_T	= Fuel volume fraction	TOTALS
	S(11)	∇_P/∇_T	= Payload volume fraction	TOTALS
15.	C(1)	C_1	= cost of Group 1	COSTS
	C(2)	C_2	= cost of Group 2	COSTS
	C(3)	C_3	= cost of Group 3	COSTS
	C(4)	C_4	= cost of Group 4	COSTS
	C(5)	C_5	= cost of Group 5	COSTS
	C(6)	C_6	= cost of Group 6	COSTS
	C(7)	C_7	= cost of empty ship	COSTS
	C(8)	C_8	= cost of payload	COSTS
16.	C(9)	C_9	= base cost of first ship	COSTS
	C(10)	C_{10}	= average cost per ship	COSTS
	C(11)	C_{11}	= life cost of personnel pay and allowances	COSTS

SUBROUTINE PRTOUT

			Subroutine where defined
C(12)	C_{12}	= life cost of maintenance	COSTS
C(13)	C_{13}	= life cost of operations, except energy	COSTS
C(14)	C_{14}	= life cost of major support	COSTS
C(15)	C_{15}	= life cost of fuel	
C(16)	C_{16}	= total life cost	COSTS

PAGES 2 and 3 - BSCI 3-digit Breakdown

Column 1	Identification	PRTOUT
Column 2	BSCI number	READIN
Column 3	Weight fractions = weight / W_T	PRTOUT
Column 4	Volume fractions = volume / ∇_T	PRTOUT
Column 5	VCG / hull depth	TOTALS
Column 6	Weight in lb = 2240 (weight in long tons)	PRTOUT
Column 7	Weight in long tons	TOTALS
Column 8	Weight in metric tons = 1.016047 (weight in long tons)	PRTOUT
Column 9	Volume in ft^3	TOTALS
Column 10	Volume in M^3 = 0.0283168 (volume in ft^3)	PRTOUT
Column 11	K-factor from input Cards 16-25	READIN

			Subroutines where defined
PAGE 4 - Hull Geometry			
1. TPARENT	Identification for hull design		READIN
2. DLBS	Δ	= displacement in lb	NEWHUL
DTONS	Δ_{LT}	= displacement in tons	PHFMOPT
PL	L_P	= projected chine length in ft	PHFMOPT
BPX	B_{PX}	= maximum chine beam in ft	PHFMOPT
HM	T	= draft at midships in ft	NEWHUL
HDM	H_h	= hull depth at midships in ft	PHFMOPT
DZS	ΔZ_S	in ft (see Figure 1)	NEWVOL
KB	$\overline{KB}$	= vertical center of buoyancy above baseline in ft	NEWHUL
BM	$\overline{BM}$	= transverse metacenter above center of buoyancy in ft	NEWHUL
KM	$\overline{KM}$	= transverse metacenter above baseline in ft	NEWHUL
GM	$\overline{GM}$	= transverse metacentric height in ft	READIN
KG	$\overline{KG}$	= vertical center of gravity above baseline in ft	NEWHUL
XLCG	$\overline{AG}$	= longitudinal center of gravity forward of transom in ft	NEWHUL
3a. XLP(1)	X/L_P	= longitudinal location of section, nondimensionalized	READIN
XFT	X	= distance of section forward of transom in ft	PRTOUT
ZS(1)	Z_S'	= deck height in ft	NEWVOL
ZC(1)	Z_C	= chine height in ft	NEWHUL
ZK(1)	Z_K	= keel height in ft	NEWHUL
YS(1)	Y_S	= half-breadth at deck in ft	NEWVOL
YC(1)	Y_C	= half-breadth at chine in ft	NEWHUL
YK(1)	Y_K	= half-breadth at keel in ft	NEWHUL

				Subroutines where defined
	BETA(1)	β	= deadrise angle in degrees	PARENT
	AS(1)	A_S	= sectional area below deck in ft^2	NEWVOL
	VOLX	∇_S	= volume from current section to transom in ft^3 $\nabla_S = \int_0^X A_S \, dX$	PRTOUT
3b.	XLP(2) etc.	One line printed for each of NN sections in same order as line 3		

PAGE 4 - Additional Printout for Landing Craft Only

4a.	XLBOWR	L_{bow}	= length of bow ramp in ft	READIN
	BBOWR	B_{bow}	= breadth of bow ramp in ft	READIN
	ABOWR	A_{br}	= area of bow ramp in ft^2	STRUCT
4b.	XLWELL	L_{well}	= length of well deck in ft	READIN
	BWELL	B_{well}	= breadth of well deck in ft	READIN
	ZWELL	Z_{well}	= height of well deck above baseline in ft	READIN
	AWELL	A_{bw}	= area of well deck in ft	STRUCT
4c.	XLAFTR	L_{aft}	= length of aft (drive-through) ramp in ft	STRUCT
	BAFTR	B_{aft}	= breadth of aft ramp in ft	READIN
	ZAFTR	Z_{aft}	= height of aft ramp above baseline in ft	READIN
	AAFTR	A_{ba}	= area of aft ramp in ft	STRUCT

				Subroutines where defined
PAGE 4 - Accelerations				
5.	SEA STATE	ss	= sea state number	PRTOUT
6.	H13-FT	$H_{1/3}$	= significant wave height in ft corresponding to upper bound of sea state	PRTOUT
7a.	SPEED(1)	V_K	= speed in knots	READIN
	RW	R/W	= resistance-weight ratio from Savitsky equations	PRTOUT
	TRIM	τ	= trim angle in degrees from Savitsky equations	PRTOUT
	CG ACC	a_{CG}	= average 1/10 highest vertical accelerations at center of gravity in g's	PRTOUT
	BOW ACC	a_{BOW}	= average 1/10 highest vertical accelerations at 90% L_{OA} forward of transom in g's	PRTOUT
	FIXED TRIM	τ'	= fixed trim angle of 2.5 deg	PRTOUT
	CG ACC	a_{CG}'	= accelerations at center of gravity when trim is 2.5 deg	PRTOUT
	BOW ACC	a_{BOW}'	= bow accelerations when trim is 2.5 deg	PRTOUT
7b.	SPEED(2)			
7c.		One line printed for each input speed		
.				
.				

Notes: $a_{CG} = 7.0\ (H_{1/3}/B_{PX})\ (1 + \tau/2)^{0.25}\ (L_P/B_{PX})^{-1.25}\ (F_{n\nabla})$

$$a_{BOW} = 10.5\ (H_{1/3}/B_{PX})\ (1 + \tau/2)^{0.5}\ (L_P/B_{PX})^{-0.75}\ (F_{n\nabla})^{0.75}$$

NAME: SUBROUTINE PARENT

PURPOSE: Nondimensionalize offsets of parent hull form

CALLING SEQUENCE: CALL PARENT

SUBPROGRAM CALLED: SIMPUN

INPUT: Via COMMON blocks

PL	L_P	= projected chine length of parent form, from input Card 2
BPX	B_{PX}	= maximum chine beam of parent form, from input Card 2
NN	n	= total number of sections, from input Card 3
M	m	= index of section at midships, from input Card 3
OFFSETS	Y_K, Z_K, Y_C, Z_C, Y_S, Z_S at each section X/L_P, from Card Set 5	
DZS	ΔZ_S of parent, constant at all sections, from input Card 2	
ZS(M)	Z_{S_m}	= (hull depth - ΔZ_S) of parent at midships

OUTPUT: Via COMMON blocks

AAP	A_P	= projected planing bottom area of parent $= \int Y_C \, dX$
BPA	B_{PA}	= mean beam over chine of parent = A_P/L_P
BPXBPA	(B_{PX}/B_{PA})	
DZSZSM	$\left(\Delta Z_S/Z_{S_m}\right)$	
I	Index for DO LOOP I = 1, NN	
YCBPA(I)	(Y_C/B_{PA})	= nondimensional half-breadth at chine
YKBPA(I)	(Y_K/B_{PA})	= nondimensional half-breadth at keel
ZCBPA(I)	(Z_C/B_{PA})	= nondimensional height of chine from baseline
ZKBPA(I)	(Z_K/B_{PA})	= nondimensional height of keel from baseline
ZSZSM(I)	$\left(Z_S/Z_{S_m}\right)$	= nondimensional deck height
GAMA(I)	γ	= angle of hull sides from vertical in deg

TANG(I)	tan γ	$= (Y_S - Y_C)/(Z_S - Z_C)$
COSG(I)	cos γ	
BETA(I)	β	= deadrise angle in deg
TANB(I)	tan β	$= (Z_C - Z_K)/(Y_C - Y_K)$
COSB(I)	cos β	

NAME:	SUBROUTINE NEWHUL	
PURPOSE:	Calculate offsets and hydrostatics for hull with new length, beam, and displacement from nondimensionalized parent form	
CALLING SEQUENCE:	CALL NEWHUL	
SUBPROGRAM CALLED:	SIMPUN, YINTX	
INPUT:	Via COMMON blocks	
PL	L_P	= projected chine length of new hull in ft, from input Card 29
BPX	B_{PX}	= maximum chine beam of new hull in ft, from PHFMOPT
DTONS	Δ_{LT}	= displacement of new hull in long tons, from PHFMOPT
GM	$\overline{GM}$	= required metacentric height in ft, from Card 9
NN	n	= total number of sections, from Card 3
Other	Nondimensional data from Subroutine PARENT	
OUTPUT:	Via COMMON blocks	
DLBS	Δ	= displacement in lb = $\Delta_{LT} \times 2240$
VOL	∇	= displaced volume in $ft^3 = \Delta/\rho g$
RLB	L/B	= length-beam ratio = L_P/B_{PX}
SLR	$L_P/\nabla^{1/3}$	= slenderness ratio
BPA	B_{PA}	= average chine beam of new hull in ft = $B_{PX}/(B_{PX}/B_{PA})$
AAP	A_P	= projected planing bottom area of new hull in ft = $B_{PA} \times L_P$
APV	$A_P/\nabla^{2/3}$	= loading coefficient of new hull
I	Index for DO LOOP I = 1, NN	
YC(I)	Y_C	= new half-breadth at chine in ft = $(Y_C/B_{PA}) \times B_{PA}$
YK(I)	Y_K	= new half-breadth at keel in ft = $(Y_K/B_{PA}) \times B_{PA}$
ZC(I)	Z_C	= new height at chine in ft = $(Z_C/B_{PA}) \times B_{PA}$
ZK(I)	Z_K	= new height at keel in ft = $(Z_K/B_{PA}) \times B_{PA}$
	All hulls have same deadrise angles β as parent	
GKC(I)	G_{KC}	= half-girth of hull bottom in ft, keel centerline to chine = $Y_K + (Y_C-Y_K)/\cos\beta$

ZW	Z_W	= height of still waterline above baseline in ft
		Program calculates displacements at six arbitrary waterlines, and interpolates to obtain the waterline for the required displaced volume ∇. Only waterlines parallel to the baseline are considered.
AW(I)	A_W	= total sectional area below waterline in ft
AWZ(I)	M_Z	= moment of A_W about the baseline
		Each section is divided into triangles and rectangles below the waterline to calculate A_W and M_Z.
AWX(I)	M_X/L_P	= moment of A_W about the transom $= A_W \times (X/L_P)$
YW3(I)	b^3	= half-breadth at waterline, cubed = $Y_W{}^3$
VOLW	∇	= check of displaced volume in ft^3 = $\int A_W\, dX$
XCG	LCG/L_P	$= \int (M_X/L_P)\, dX \,/ \int A_W\, dX$
XLCG	LCG	= distance of center of gravity forward of transom in ft
KB	$\overline{KB}$	= vertical center of buoyancy VCB above baseline in ft $= \int M_Z\, dX \,/ \int A_W\, dX$
BM	$\overline{BM}$	= vertical distance from VCB to metacenter in ft $= 2/3 \int b^3\, dX \,/ \int A_W\, dX$
KM	$\overline{KM}$	= height of metacenter above baseline in ft $= \overline{KB} + \overline{BM}$
KG	$\overline{KG}$	= vertical center of gravity VCG above baseline in ft $= \overline{KM} - \overline{GM}$
HM	T	= draft at midships in ft = Z_W
HT	T_t	= draft at transom in ft = $Z_W - Z_{K_1}$
HTM	T_t / T	
CB	C_B	= block coefficient = $\nabla/(L_P\, B_{PX}\, T)$
VOLSM(K), ZSMZWL(K), (K=1,6)		Array of hull volumes calculated at six arbitrary deck heights Not used in current program, see Subroutine NEWVOL

NAME:	SUBROUTINE NEWVOL
PURPOSE:	Calculate enclosed volume and hull density for new hull depth
CALLING SEQUENCE:	CALL NEWVOL
INPUT:	Via COMMON blocks
HDM	H_h = new hull depth, keel to main deck at midships, in ft from PHFMOPT
Other	Keel and chine offsets for new hull from Subroutine NEWHUL
Other	Nondimensional deck offsets from Subroutine PARENT
Other	Superstructure dimensions from Subroutine CREWSS
OUTPUT:	Via COMMON blocks
ZS(M)	Z_{S_m} = hull depth at midships - ΔZ_S in ft $= H_h / [1 + (\Delta Z_S/Z_{S_m})]$
DZS	ΔZ_S of new hull in ft = $Z_{S_m} \times (\Delta Z_S/Z_{S_m})$
I	Index of DO LOOP I = 1, NN
ZS(I)	Z_S = deck height - ΔZ_S in ft = $(Z_S/Z_{S_m}) \times Z_{S_m}$
ZS(I)	Z_S' = new deck height in ft - $Z_S + \Delta Z_S$
YS(I)	Y_S = new half-breadth at deck in ft $= Y_C + (Z_S - Z_C) \tan \gamma$
GCS(I)	G_{CS} = girth of one side, chine to deck, in ft $= \Delta Z_S + (Z_S - Z_C)/\cos \gamma$ Sides maintain same slope γ as parent form.
AS(I)	A_S = total sectional area, keel to deck, in ft^2
ZM(I)	C_S = height of centroid of A_S above baseline in ft Each section is divided into triangles and rectangles to calculate A_S and C_S.
VOLH	∇_h = hull volume, up to main deck, in ft^3 $= \int A_S \, dX$
VOLSS	∇_{ss} = volume enclosed by superstructure in ft^3
VOLT	∇_T = total volume in ft^3 = $\nabla_h + \nabla_{ss}$
VDENS	Δ/∇_h = vehicle density in lb/ft^3

ZSSFT	Z_{ss}'	= height of centroid of superstructure above deck in ft
	Z_{ss}'	= 6.0 if H_{ss} = 8.0; Z_{ss}' = 9.0 if H_{ss} = 16.0
ZSS	Z_{ss}	= superstructure centroid above baseline / hull depth
		= $(H_h+Z_{ss}')/H_h$
ARH	A_h	= area of profile up to main deck in ft $\approx L_P \times H_h$
ARSS	A_{ss}	= area of profile of superstructure in ft
		= $L_{ss} \times H_{ss}$
ZPC	Z_{PC}	= height of profile centroid above baseline / hull depth
		= $(0.5\ A_h+Z_{ss}\ A_{ss})/(A_h+A_{ss})$
HMB	H_{mb}	= height of machinery box, main engine room, in ft
		= H_h

NAME:	SUBROUTINE CREWSS
PURPOSE:	Define ship's complement if not specified on input cards Define superstructure dimensions
CALLING SEQUENCE:	CALL CREWSS
INPUT:	Via COMMON blocks
DTONS	Δ_{LT} = ship displacement in long tons, from PHFMOPT
PL	L_P = ship length in ft, from input Card 29
ACC	Total accommodations--optional input on Card 10
CREW	Number of enlisted men--optional input on Card 10
CPO	Number of CPO's--optional input on Card 10
OFF	Number of officers--optional input on Card 10
FVOLSS	Volume of superstructure in ft^3--optional input on Card 11
OUTPUT:	Via COMMON blocks
W	W = total ship weight in long tons = Δ_{LT}
DMULT	M_Δ = multiplier for items which vary with ship size = $[\ell n\ (W+90)-2.55]/4.92$ for $W < 2000$ = 1.0 for $W \geq 2000$
NACCM	Number of personnel concerned with military payload NACCM = 0.052 W if $W \leq 100$ NACCM = 0.012 W + 4 if $W > 100$
NACCS	Number of personnel for operation of ship = 0.035W + 4
ACC	Total accommodations = NACCM + NACCS, rounded up unless ACC has been specified on Card 10
CREW	Number of enlisted men = 5/7 × ACC unless CREW has been specified on Card 10
CPO	Number of CPO's = 1/7 × ACC unless CREW has been specified on Card 10
OFF	Number of officers = 1/7 × ACC unless CREW has been specified on Card 10
	Note: CPO and/or OFF can be set to 0 by input card if CREW is specified greater than 0. However, if CREW is set to 0 or blank space left on input card, then CREW, CPO, and OFF are calculated from above equations.

VOLSS	∇_{ss} = volume enclosed by superstructure in ft^3 If input value of FVOLSS > 0, then ∇_{ss} = FVOLSS Otherwise, $\nabla_{ss} = 70 \times W \times M_{\Delta}$
HSS	H_{ss} = height of superstructure in ft = 8.0 initially
BSS	B_{ss} = breadth of superstructure in ft = B_{PA}
XLSS	L_{ss} = length of superstructure in ft = $\nabla_{ss}/(H_{ss} \times B_{ss})$ If L_{ss} calculated is greater than 0.7 L_P, increase H_{ss} by increment of 8 ft, and recalculate B_{ss} and L_{ss}.
ARSS	A_{ss} = profile area of superstructure in ft^2 $= L_{ss} \times H_{ss}$
VSSW	∇_{ss}/W

NAME:	SUBROUTINE STRUCT (to be used when ILC=0 and IMAT<3)	
PURPOSE:	Calculate weights, volumes, and VCG's of major structures, Group 1, for <u>conventional planing hull of aluminum or steel</u>	
CALLING SEQUENCE:	CALL STRUCT	
INPUT:	Via COMMON blocks	
IMAT	Control for type of structural material, from input Card 6 IMAT = 1 for aluminum IMAT = 2 for steel	
WSFMIN	S_{min}	= minimum unit weight of plating in lb/ft^2, from Card 11
WSLOPE	S_P	= Slope of unit weight curves for stiffened plating as function of design load, from Card 11
STRESS	σ_{limit}	= Stress limit of material in lb/in.^{2}, from Card 11
DMAT	γ_{mat}	= density of structural material in lb/ft^3, from Card 11
Other	Hull geometry from Subroutines NEWHUL, NEWVOL, etc.	
OUTPUT:	Via COMMON blocks	

A. GENERAL EQUATIONS

PRES	P	= design pressure on plating in lb/in.^{2}
	S	= unit weight of stiffened plating in lb/ft^2
* UNITWT	S	= $S_{min} + (P \times S_P)$ for hull bottom, decks, and bulkheads Curves shown in Figure 4 for different materials
	S	= $f(L_P)$ for hull sides Curves shown in Figure 5 for different materials
* THICKN	t	= thickness of plating in inches = $12\ S/\gamma_{mat}$
	D	= depth of plating web in ft
* DEPTHA	D	= (S-1.45)/12 for aluminum
* DEPTHS	D	= (3.0+0.1 P)/12 for steel
DPMIN	D_{min}	= minimum depth of plating web = 0.25 ft

*UNITWT, THICKN, DEPTHA and DEPTHS are Statement Functions defined at beginning of Subroutine STRUCT.

B. PLATFORM DECKS

NPL	n_{pl}	= number of platform decks, excluding main deck
	n_{pl}	= 0 if H_h is 10 ft or less
	n_{pl}	= 1 if H_h is between 10 and 20 ft
	n_{pl}	= 2 if H_h is 20 ft or greater
ZSP1, ZSP2	H_{pl}	= distance from lower, upper platforms to main deck = 8 or 16 ft - see location of platforms in Figure 2
PRES	P_{pl}	= design pressure on platform in lb/in.^{2} = 64 $(H_{pl}+4)/144$
WSF	S_{pl}	= unit weight of platform in lb/ft^2, Figure 4
APL1, APL2	A_{pl}	= area of platform in ft^2 Platforms extend length of hull, except engine room
DPL1, DPL2	D_{pl}	= depth of platform web in ft use general equations for aluminum or steel
WPL1, WPL2	W_{pl}	= weight of platform in lb = $A_{pl} \times S_{pl}$
VPL1, VPL2	V_{pl}	= volume of platform in ft^3 = $A_{pl} \times D_{pl}$
ZPL1, ZPL2	Z_{pl}	= VCG of platform in ft = $(Z_S$ at $X/L_P=0.75) - H_{pl}$

C. TRANSVERSE BULKHEADS

NTB	n_{tb}	= number of transverse bulkheads input = 9 see location of transverse bulkheads in Figure 2 number will be reduced later if displacement is less than 70 tons
J	Index for DO LOOP J = 1, NTB	
ZKS	H_{tb}	= height of transverse bulkhead in ft = (Z_S-Z_K) at location of bulkhead
ZF	H_{ft}	= height of fuel tank coincident with bulkhead see location of fuel tanks in Figure 2
	$\ddot{N}$	= design acceleration in g's at bulkhead = 2.0, 4.0, 5.5 g's for aft, mid, forward fuel tanks

PRES	P_{tb}	= design pressure on bulkhead in lb/in.^{2} = $64\ (H_{tb}+4)/144$ or $52\ (H_{ft}\ \ddot{N})/144$ whichever is greater
WSF	S_{tb}	= unit weight of transverse bulkhead, Figure 4
AS	A_{tb}	= area of transverse bulkhead in ft^2 = A_S = total sectional area from Subroutine NEWVOL
DTB	D_{tb}	= depth of bulkhead web in ft
WTB(J)	W_{tb}	= weight of transverse bulkhead in lb = $A_{tb} \times S_{tb}$
VTB	∇_{tb}	= volume of transverse bulkhead in ft^3 = $A_{tb} \times D_{tb}$
ZTB(J)	Z_{tb}	= VCG of transverse bulkhead in ft = C_S = centroid of section from Subroutine NEWVOL
WTBJ	ΣW_{tb}	= total weight of all transverse bulkheads in lb
VTBT	$\Sigma\nabla_{tb}$	= total volume of transverse bulkheads in ft^3
ZTBT	$\bar{Z}_{tb}$	= net VCG of all transverse bulkheads in ft = $\Sigma(Z_{tb} \times W_{tb})/\Sigma W_{tb}$

D. LONGITUDINAL BULKHEADS

NLB	$n_{\ell b}$	= number of longitudinal bulkheads
	$n_{\ell b}$	= 0 if hull depth is 10 ft or less
	$n_{\ell b}$	= 1 if midship chine beam is 20 ft or less
	$n_{\ell b}$	= 2 if midship chine beam is between 20 and 30 ft
	$n_{\ell b}$	= 3 if midship chine beam is greater than 30 ft

Longitudinal bulkheads are equally spaced across breadth of hull; a single bulkhead is on centerline. Longitudinal bulkheads extend full length of hull below the lower platform deck. Bulkheads not on centerline are watertight; centerline bulkhead is not watertight.

WSF	$S_{\ell b}$	= unit weight of non-centerline bulkheads in lb/ft^2 = unit weight of lower platform deck (same design pressure)

WSFMIN	$S_{\ell b}$	= unit weight of centerline bulkhead in lb/ft^2 = S_{min} (design pressure = 0, since not watertight)
J	Index for DO LOOP J = 1, NLB	
AREAP	$A_{\ell b}$	= area of longitudinal bulkhead in ft^2
WLB(J)	$W_{\ell b}$	= weight of longitudinal bulkhead in lb = $A_{\ell b} \times S_{\ell b}$
DLB	$D_{\ell b}$	= depth of longitudinal bulkhead web in ft
	$\nabla_{\ell b}$	= volume of longitudinal bulkhead in ft^3 = $A_{\ell b} \times D_{\ell b}$
ZLB(J)	$Z_{\ell b}$	= VCG of longitudinal bulkhead in ft
WLBT	$\Sigma W_{\ell b}$	= total weight of all longitudinal bulkheads in lb
VLBT	$\Sigma \nabla_{\ell b}$	= total volume of all longitudinal bulkheads in ft^3
ZLBT	$\bar{Z}_{\ell b}$	= net VCG of all longitudinal bulkheads in ft^3 = $\Sigma(W_{\ell b} \times Z_{\ell b})/\Sigma W_{\ell b}$

E. HULL BOTTOM - KEEL TO CHINE

PRESHH	P_{hh}	= pressure due to hydrostatic head in $lb/in.^2$ = $64\left(Z_{S_m}+4\right)/144$
GKC(M40)	G_b	= half-girth from keel to chine in ft at $X/L_p = 0.6$
	$\ddot{N}_{CG}$	= design acceleration at CG in g's = 3.0
PRESF	P_{bf}	= design pressure on forward 40 percent of bottom in $lb/in.^2$ = $9\Delta\ (1+\ddot{N}_{CG})/(2G_b\ L_p)/144$ or P_{hh} if greater
PRESA	P_{ba}	= design pressure on aft 60 percent of bottom in $lb/in.^2$ = $1/2\ P_{bf}$ or P_{hh} whichever is greater
WSF1F	S_{bf}	= unit weight of forward bottom plating in lb/ft^2, Figure 4
WSF1A	S_{ba}	= unit weight of aft bottom plating in lb/ft^2, Figure 4

ABOTTF	A_{bf}	= area of forward 40 percent of bottom in ft^2 $= 2 \int_{0.6\,L_P}^{L_P} G_{KC}\, dX$
ABOTTA	A_{ba}	= area of aft 60 percent of bottom in ft^2 $= 2 \int_{0}^{0.6\,L_P} G_{KC}\, dX$
WBOTT	W_b	= weight of bottom plating in lb $= (A_{bf} \times S_{bf}) + (A_{ba} \times S_{ba})$
VBOTT	∇_b	= volume of bottom plating in $ft^3 = W_b/\gamma_{mat}$
ZBOTT	Z_b	= VCG of bottom plating in ft

F. HULL SIDES - CHINE TO MAIN DECK

WSF2 — S_s = unit weight of side plating in lb/ft^2, Figure 5

Aluminum hull: $S_s = 2.4 + 0.022\, L_P$, if $L_P \leq 150$ ft

$S_s = 1.2 + 0.030\, L_P$, if $L_P > 150$ ft

Steel hull: $S_s = 5.5 + 0.0188\, L_P$, for all L_P

minimum value of S_s is S_{min}

ASIDE	A_s	= area of both sides in $ft^2 = 2 \int_{0}^{L_P} G_{CS}\, dX$
WSIDE	W_s	= weight of side plating in lb $= A_s \times S_s$
DSIDE	D_s	= depth of side plating web in ft
VSIDE	∇_s	= volume of side plating in $ft^3 = A_s \times D_s$
ZSIDE	Z_s	= VCG of side plating in ft

G. MAIN DECK

PRES	P_d	= design pressure on main deck in $lb/in.^2$ $= 64 \times 4/144$
WSF3	S_d	= unit weight of main deck in lb/ft^2, Figure 4
ADECK	A_d	= area of main deck in $ft^2 = 2 \int Y_S\, dX$
DDECK	D_d	= depth of main deck web in ft
WDECK	W_d	= weight of main deck in lb $= A_d \times S_d$

VDECK	∇_d	= volume of main deck in $ft^2 = A_d \times D_d$
ZDECK	Z_d	= VCG of main deck in ft

H. STRESS CALCULATION AT MIDSHIPS

T1	t_1	= thickness of bottom plating in inches $= 12\ S_{ba}/\gamma_{mat}$
T2	t_2	= thickness of side plating in inches $= 12\ S_s/\gamma_{mat}$
T3	t_3	= thickness of main deck in inches $= 12\ S_d/\gamma_{mat}$
Y1	ℓ_1	= half length of bottom at midships in inches $= 12\ G_{KC_m}$
Y2	ℓ_2	= half length of sides at midships in inches $= 12\ G_{CS_m}$
Y3	ℓ_3	= effective half length of deck at midships in inches $= (2/3)\ (12\ Y_s)$
A1	A_1	= half area of bottom plating at midships in $in.^2 = t_1\ \ell_1$
A2	A_2	= half area of side plating at midships in $in.^2 = t_2\ \ell_2$
A3	A_3	= half area of main deck at midships in $in.^2 = t_3\ \ell_3$
Z1	Z_1	= VCG of A_1 in inches $= 12\left[Z_{K_m} + \frac{1}{2}\left(Z_{C_m} - Z_{K_m}\right)\right]$
Z2	Z_2	= VCG of A_2 in inches $= 12\left[Z_{C_m} + \frac{1}{2}\left(Z_{S_m} - Z_{C_m}\right)\right]$
Z3	Z_3	= VCG of A_3 in inches $= 12 \times Z_{S_m}$
Z22	Z_{22}	= vertical height of sides in inches $= 12\left(Z_{S_m} - Z_{C_m}\right)$
ZNA	Z_{NA}	= height of neutral axis at midships above keel in inches $= (A_1Z_1 + A_2Z_2 + A_3Z_3)\ /\ (A_1 + A_2 + A_3)$

SI	I_m	= sectional inertia in in.^{4}
		$= 2\ (A_1Z_1{}^2 + A_2Z_2{}^2 + A_3Z_3{}^2 + A_2Z_{22}{}^2/12)$
		$- (A_1+A_2+A_3)\ Z_{NA}{}^2$
SM	S_m	= least section modulus in in.^{3}
		$= 1/Z_{NA}$ or $1/(H_h-Z_{NA})$ whichever is smaller
	$\ddot{N}_B$	= design bow acceleration in g's = 7.55
	$\ddot{N}_{CG}$	= design CG acceleration in g's = 3.0
TM	M_b	= bending moment at midships in in.-lb
		$= 12\ L_P\ \Delta\ (128\ \ddot{N}_B-178\ddot{N}_{CG}-50)/1920$
PSI	σ_{max}	= maximum stress in lb/in.^{2} $= M_b/S_m$

If $\sigma_{max} \le \sigma_{limit}$, original plating thicknesses are OK

If $\sigma_{max} > \sigma_{limit}$ and $Z_{NA} < 0.5\ H_h$, increase t_3 by 0.02 in. and recalculate σ_{max}

If $\sigma_{max} > \sigma_{limit}$ and $Z_{NA} > 0.5\ H_h$, increase t_3 and t_1 by 0.02 in. and recalculate σ_{max}

WSF1A	S_{ba}	= unit weight of aft bottom plating in lb/ft^2
		$= t_1\ \gamma_{mat}/12$ recalculated if t_1 is increased
WSF3	S_d	= unit weight of deck in lb/ft^2
		$= t_3\ \gamma_{mat}/12$ recalculated if t_3 is increased

I. FRAMING - LONGITUDINAL AND TRANSVERSE

WFRAM — W_{fr} = total weight of framing in lb, Figure 6

Aluminum hull: $W_{fr} = 0.70\ \nabla_h$

Steel hull: $W_{fr} = 2.1\ \nabla_h$; if $\nabla_h \le 3 \times 10^4$

$W_{fr} = 1.1\ \nabla_h + 3 \times 10^4$; $3 \times 10^4 < \nabla_h \le 1 \times 10^5$

$W_{fr} = 0.93\ \nabla_h + 4.7 \times 10^4$; if $\nabla_h > 1 \times 10^5$

VFRAM — ∇_{fr} = volume of framing in ft^3

Aluminum hull: $\nabla_{fr} = 0.06\ W_{fr}$

Steel hull: $\nabla_{fr} = 0.03\ W_{fr}$

ZFRAM	Z_{fr}	= VCG of framing in ft = centroid of ∇_h

J. SUMMARY OF STRUCTURES--Group 1

W1(2)	W_{100A}	= weight of plating for hull bottom in tons = $W_b/2240$
Z1(2)	Z_{100A}	= VCG of bottom plating / hull depth = Z_b/H_h
V1(2)	∇_{100A}	= volume of bottom plating in $ft^3 = \nabla_b$
W1(3)	W_{100B}	= weight of plating for hull sides in tons = $W_s/2240$
Z1(3)	Z_{100B}	= VCG of side plating / hull depth = Z_s/H_h
V1(3)	∇_{100B}	= volume of side plating in $ft^3 = \nabla_s$
W1(4)	W_{101}	= weight of framing in tons = $W_{fr}/2240$
Z1(4)	Z_{101}	= VCG of framing / hull depth = Z_{fr}/H_h
V1(4)	∇_{101}	= volume of framing in $ft^3 = \nabla_{fr}$
W1(5)	W_{103A}	= weight of upper platform in tons = $W_{pl_2}/2240$
Z1(5)	Z_{103A}	= VCG of upper platform / hull depth = Z_{pl_2}/H_h
V1(5)	∇_{103A}	= volume of upper platform in $ft^3 = \nabla_{pl_2}$
W1(6)	W_{103B}	= weight of lower platform in tons = $W_{pl_1}/2240$
Z1(6)	Z_{103B}	= VCG of lower platform / hull depth = Z_{pl_1}/H_h
V1(6)	∇_{103B}	= volume of lower platform in $ft^3 = \nabla_{pl_1}$
W1(7)	W_{107}	= weight of main deck in tons = $W_d/2240$
Z1(7)	Z_{107}	= VCG of main deck / hull depth = Z_d/H_h
V1(7)	∇_{107}	= volume of main deck in $ft^3 = \nabla_d$
NTB	n_{tb}'	= revised number of transverse bulkheads
	n_{tb}'	= 1, if $\Delta_{LT} \leq 10$
	n_{tb}'	= $3.663 \ln (\Delta_{LT}/8.1)$, if $10 < \Delta_{LT} < 70$
	n_{tb}'	= 9, if $\Delta_{LT} \geq 70$

W1(8) W_{114A} = weight of transverse bulkheads in tons
$= \Sigma W_{tb}\ (n_{tb}'/9)/2240$

Z1(8) Z_{114A} = VCG of transverse bulkheads / hull depth
$= \bar{Z}_{tb}/H_h$

V1(8) ∇_{114A} = volume of transverse bulkheads in ft^3
$= \Sigma\nabla_{tb}\ (n_{tb}/9)$

W1(9) W_{114B} = weight of longitudinal bulkheads in tons
$= \Sigma W_{\ell b}/2240$

Z1(9) Z_{114B} = VCG of longitudinal bulkheads / hull depth
$= \bar{Z}_{\ell b}/H_h$

V1(9) ∇_{114B} = volume of longitudinal bulkheads in ft^3
$= \Sigma\nabla_{\ell b}$

Subscripts are BSCI 3-digit code

The superstructure, foundations for propulsion and other equipment, and attachment are calculated in Subroutine TOTALS.

NAME:	SUBROUTINE STRUCT (to be used when ILC=0 and IMAT>2)
PURPOSE:	Calculate weights, volumes, and VCG's of major structures, Group 1, for <u>planing hulls of glass reinforced plastic (GRP)</u>
CALLING SEQUENCE:	CALL STRUCT
INPUT:	Via COMMON blocks
IMAT	Control for type of construction, from input Card 6 IMAT = 3 for GRP single skin, with single skin bulkheads IMAT = 4 for GRP single skin, with sandwich plate bulkheads IMAT = 5 for GRP sandwich plate, with sandwich plate bulkheads
IFRM	Control type of framing IFRM = 1 for transverse framing IFRM = 2 for longitudinal framing
WSFMIN	S_{min} = minimum unit weight of plating in lb/ft^2, from Card 11; 2.5 lb/ft^2 for sandwich plate; 3.25 lb/ft^2 for single skin
WSLOPE	S_P = slope of unit weight curves for bottom plating as function of design load, from Card 11
STRESS	σ_{limit} = stress limit in lb/in^2, from Card 11
DMAT	γ_{mat} = density of material in lb/ft^3, from Card 11
Other	Hull geometry for subroutines NEWHULL, NEWVOL, etc.
OUTPUT:	Via COMMON blocks
A. GENERAL	
PRES	p = design pressure on plating in lb/in^2
UNITWT	S = unit weight of plating in lb/ft^2
	Curves of unit weight for GRP single skin and sandwich plate are shown in Figures 4 and 5.
B. PLATFORM DECKS	
NPL	n_{pl} = number of platform decks, excluding main deck n_{pl} = 0 if H_h is 10 ft or less n_{pl} = 1 if H_h is between 10 and 20 ft n_{pl} = 2 if H_h is 20 ft or greater

ZSP1 ZSP2	H_{pl}	= distance from lower, upper platforms to main deck = 8 or 16 ft - see location of platforms in Figure 2
PRES	P_{pl}	= design pressure on platform in lb/in.^{2} = 64 $(H_{pl}+4)/144$
WSF	S_{pl}	= unit weight of platform in lb/ft^2, Figure 4 = 2.50 + 0.140 P_{pl} for sandwich plate (IMAT=5) = 3.25 + 0.192 P_{pl} for single skin (IMAT=3 or4)
APL1 APL2	A_{pl}	= area of platform in ft^2; platforms extend length of hull, except engine room
WPL1 WPL2	W_{pl}	= weight of platform in lb = $A_{pl} \times S_{pl}$
ZPL1 ZPL2	Z_{pl}	= VCG of platform in ft = (Z_S at X/L_P=0.75) - H_{pl}

C. TRANSVERSE BULKHEADS

NTB	n_{tb}	= number of transverse bulkheads input = 9 see location of transverse bulkheads in Figure 2 number will be reduced later if displacement is less than 70 tons
J		Index for DO LOOP J = 1, NTB
ZKS	H_{tb}	= height of transverse bulkhead in ft = (Z_S-Z_K) at location of bulkhead
ZF	H_{ft}	= height of fuel tank coincident with bulkhead see location of fuel tanks in Figure 2
	$\ddot{N}$	= design acceleration in g's at bulkhead = 2.0, 4.0, 5.5 g's for aft, mid, forward fuel tanks
PRES	P_{tb}	= design pressure on bulkhead in lb/in.^{2} = 64 $(H_{tb}+4)/144$ or 52 $(H_{ft}\ N)/144$ whichever is greater
WSF	S_{tb}	= unit weight of transverse bulkhead, Figure 4 = 2.50 + 0.221 P_{tb} for sandwich plate (IMAT=4 or 5) = 3.25 + 0.280 P_{tb} for single skin (IMAT=3)
AS	A_{tb}	= area of transverse bulkhead in ft^2 = A_S = total sectional area from Subroutine NEWVOL
WTB(J)	W_{tb}	= weight of transverse bulkhead in lb = $A_{tb} \times S_{tb}$

ZTB(J) Z_{tb} = VCG of transverse bulkhead in ft = C_S

= centroid of section from Subroutine NEWVOL

WTBJ ΣW_{tb} = total weight of all transverse bulkheads in lb

ZTBT $\overline{Z}_{tb}$ = net VCG of all transverse bulkheads in ft

$= \Sigma(Z_{tb} x W_{tb})/\Sigma W_{tb}$

D. LONGITUDINAL BULKHEADS

NLB $n_{\ell b}$ = number of longitudinal bulkheads

$n_{\ell b}$ = 0 if hull depth is 10 ft or less

$n_{\ell b}$ = 1 if midship chine beam is 20 ft or less

$n_{\ell b}$ = 2 if midship chine beam is between 20 and 30 ft

$n_{\ell b}$ = 3 if midship chine beam is greater than 30 ft

Longitudinal bulkheads are equally spaced across breadth of hull; a single bulkhead is on centerline. Longitudinal bulkheads extend full length of hull below the lower platform deck. Bulkheads not on centerline are watertight; centerline bulkhead is not watertight.

WSF $S_{\ell b}$ = unit weight of noncenterline bulkheads

$= 2.50 + 0.221\ P_{\ell b}$ for sandwich plate (IMAT = 4 or 5)

$= 3.25 + 0.280\ P_{\ell b}$ for single skin (IMAT=3)

where $P_{\ell b}$ = design pressure on bulkhead

= pressure on lower platform deck

WSMIN $S_{\ell b}$ = unit weight of centerline bulkhead in lb/ft^2

= S_{min} (design pressure = 0, since not watertight)

J Index for DO LOOP J = 1, NLB

AREAP $A_{\ell b}$ = area of longitudinal bulkhead in ft^2

WLB(J) $W_{\ell b}$ = weight of longitudinal bulkhead in lb

$= A_{\ell b} \times S_{\ell b}$

ZLB(J) $Z_{\ell b}$ = VCG of longitudinal bulkhead in ft

WLBT $\Sigma W_{\ell b}$ = total weight of all longitudinal bulkheads in lb

ZLBT $\overline{Z}_{\ell b}$ = net VCG of all longitudinal bulkheads in ft^3

$= \Sigma(W_{\ell b} x Z_{\ell b})/\Sigma W_{\ell b}$

E. HULL BOTTOM - KEEL TO CHINE

PRESHH	P_{hh}	= pressure due to hydrostatic head in $lb/in.^2$
		= $64\ (Z_{S_m} + 4)\ /144$
GKC(M40)	G_b	= half-girth from keel to chine in ft at $X/L_P = 0.6$
	$\ddot{N}_{CG}$	= design acceleration at CG in g's = 3.0
PRESF	P_{bf}	= design pressure on forward 40 percent of bottom in $lb/in.^2$
		= $9\Delta\ (1+\ddot{N}_{CG})/(2G_b\ L_P)/144$ or P_{hh} if greater
PRESA	P_{ba}	= design pressure on aft 60 percent of bottom in $lb/in.^2$
		= 1/2 P_{bf} or P_{hh} whichever is greater
WSF1F	S_{bf}	= unit weight of forward bottom plating
		= $2.50 + 0.140\ P_{bf}$ for sandwich plate (IMAT=5)
		= $3.25 + 0.192\ P_{bf}$ for single skin (IMAT=3 or4)
WSF1A	S_{ba}	= unit weight of aft bottom plating
		= $2.50 + 0.140\ P_{ba}$ for sandwich plate
		= $3.25 + 0.192\ P_{ba}$ for single skin
ABOTTF	A_{bf}	= area of forward 40 percent of bottom in ft^2
		$= 2 \int_{0.6\ L_P}^{L_P} G_{KC}\ dX$
ABOTTA	A_{ba}	= area of aft 60 percent of bottom in ft^2
		$= 2 \int_{0}^{0.6\ L_P} G_{KC}\ dX$
WBOTT	W_b	= weight of bottom plating in lb
		$= (A_{bf}\ S_{bf}) + (A_{ba}\ S_{ba})$
ZBOTT	Z_b	= VCG of bottom plating in ft

F. HULL SIDES - CHINE TO MAIN DECK

WSF2	S_s	= unit weight of side plating in lb/ft^2, Figure 5
		= $1.4 + 0.0350\ L_P$ for sandwich plate (IMAT=5)
		= $2.3 + 0.0395\ L_P$ for single skin (IMAT=3 or 4) (minimum value of S_s is S_{min})

ASIDE	A_s	= area of both sides in $ft^2 = 2\int_0^{L_P} G_{CS} dX$
WSIDE	W_s	= weight of side plating in lb = $A_s \times S_s$
ZSIDE	Z_s	= VCG of side plating in ft

G. MAIN DECK

WSF3	S_d	= unit weight of main deck in lb/ft^2, Figure 5
		= unit weight of side plating S_s
ADECK	A_d	= area of main deck in $ft^2 = 2\int Y_S\, dX$
WDECK	W_d	= weight of main deck in lb = $A_d \times S_d$
ZDECK	Z_d	= VCG of main deck in ft

H. FRAMING - TRANSVERSE OR LONGITUDINAL

WFRAM	W_{fr}	= weight of framing in lb, Figure 6
		= 0.75 ∇_h for transverse framing (IFRM=1)
		= 1.20 ∇_h for longitudinal framing (IFRM=2)
ZFRAM	Z_{fr}	= VCG of framing in ft = centroid of ∇_h

I. STRESS CALCULATION AT MIDSHIPS

WFLE	W_{fle}	= longitudinally effective framing weight in lb
		= 0.36 W_{fr} for transverse framing
		= 0.48 W_{fr} for longitudinal framing
AFLE	A_{fle}	= longitudinally effective framing half-area in ft^2
		= W_{fle} / 1.40 / 2
A1P	A_1'	= effective half-area added to bottom at midship
		= 0.80 A_{fle} for transverse framing
		= 0.90 A_{fle} for longitudinal framing
A3P	A_3'	= effective half-area added to deck at midship
		= 0.20 A_{fle} for transverse framing
		= 0.10 A_{fle} for longitudinal framing

SUBROUTINE STRUCT for GRP

XKF	K_f	=	constant to take care of weight in core of stiffeners which are not effective in strength
		=	0.94 for single skin, longitudinally framed
		=	0.94 x 0.90 for sandwich plate, longitudinally framed
		=	0.60 for single skin, transversely framed
		=	0.60 x 0.70 for sandwich plate, transversely framed
T1	t_1	=	thickness of bottom plating in inches
		=	$(12\ S_{ba}/\gamma_{mat}) \times K_f$
T2	t_2	=	thickness of side plating in inches
		=	$(12\ S_s/\gamma_{mat}) \times K_f$
T3	t_3	=	thickness of main deck in inches
		=	$(12\ S_d/\gamma_{mat}) \times K_f$
Y1	ℓ_1	=	half length of bottom at midships in inches
		=	$12\ G_{KC_m}$
Y2	ℓ_2	=	half length of sides at midships in inches
		=	$12\ G_{CS_m}$
Y3	ℓ_3	=	effective half length of deck at midships in inches
		=	$(2/3)\ (12\ Y_s)$
A1	A_1	=	half area of bottom plating at midships in $in.^2$
		=	$t_1\ \ell_1 + A_1'$
A2	A_2	=	half area of side plating at midships in $in.^2$
		=	$t_2\ \ell_2$
A3	A_3	=	half area of main deck at midships in $in.^2$
		=	$t_3\ \ell_3 + A_3'$
Z1	Z_1	=	VCG of A_1 in inches $= 12[Z_{K_m} + 1/2\ (Z_{C_m} - Z_{K_m})]$
Z2	Z_2	=	VCG of A_2 in inches $= 12[Z_{C_m} + 1/2\ (Z_{S_m} - Z_{C_m})]$

Z3	Z_3	= VCG of A_3 in inches in 12 x Z_{S_m}
Z22	Z_{22}	= vertical height of sides in inches = 12 $(Z_{S_m} - Z_{C_m})$
ZNA	Z_{NA}	= height of neutral axis at midships above keel in inches = $(A_1A_1 + A_2Z_2 + A_3Z_3) / (A_1 + A_2 + A_3)$
SI	I_m	= sectional inertia in in.^{4} = $2(A_1Z_1^2 + A_2Z_2^2 + A_3Z_3^2 + A_2Z_{22}^2/12)$ $- (A_1+A_2+A_3)\ Z_{NA}^2$
SM	S_m	= least section modulus in in.^{3} = $1/Z_{NA}$ or $1/(H_h - Z_{NA})$ whichever is smaller
	$\ddot{N}_B$	= design bow acceleration in g's = 7.55
	$\ddot{N}_{CG}$	= design CG acceleration in g's = 3.0
TM	M_b	= bending moment at midships in in.-lb = $12\ L_p\ \Delta\ (128\ \ddot{N}_B - 178\ \ddot{N}_{CG} - 50)/1920$
PSI	σ_{max}	= maximum stress in lb/in.^{2} = M_b/S_m

If $\sigma_{max} \leq \sigma_{limit}$, original plating thicknesses are OK

If $\sigma_{max} > \sigma_{limit}$ and $Z_{NA} < 0.5\ H_h$, increase t_3 by 0.02 in. and recalculate σ_{max}

If $\sigma_{max} > \sigma_{limit}$ and $Z_{NA} > 0.5\ H_h$, increase t_3 and t_1 by 0.02 in. and recalculate σ_{max}

WSF1A	S_{ba}	= unit weight of aft bottom plating in lb/ft^2 = $t_1\ \sigma_{mat}\ / 12 / K_f$ recalculate if t_1 is increased
WSF3	S_d	= unit weight of deck in lb/ft^2 = $t_3\ \sigma_{mat}\ / 12 / K_f$ recalculate if t_3 is increased

J. VOLUME LOST

VI(1)	∇_1	= total volume of structure in ft^3 = $0.11\ \nabla_h + (W_{fr} / 43)$

SUBROUTINE STRUCT for GRP

ATOT	A_{tot}	= total area of hull side, bottom, main deck, platforms, and bulkheads
		$= A_s + A_{bf} + A_{ba} + A_d + A_{pl_1} + A_{pl_2} + \Sigma A_{tb} + \Sigma A_{\ell b}$
VSIDE	∇_s	= volume of sides = $\nabla_1\ A_s/A_{tot}$
VBOTT	∇_b	= volume of bottom = $\nabla_1\ (A_{bf} + A_{ba})/A_{tot}$
VDECK	∇_d	= volume of main deck = $\nabla_1\ A_d/A_{tot}$
VPL1	∇_{pl_1}	= volume of lower platform = $\nabla_1\ A_{pl_1}/A_{tot}$
VPL2	∇_{pl_2}	= volume of upper platform = $\nabla_1\ A_{pl_2}/A_{tot}$
VTBT	∇_{tb}	= volume of transverse bulkheads = $\nabla_1(\Sigma A_{tb})/A_{tot}$
VLBT	$\nabla_{\ell b}$	= volume of longitudinal bulkheads = $\nabla_1(\Sigma A_{\ell b})/A_{tot}$
VFRAM	∇_{fr}	= volume of framing = $W_{fr}/43 = 0.02326\ W_{fr}$

K. SUMMARY OF STRUCTURES--Group 1

W1(2)	W_{100A}	= weight of plating for hull bottom in tons $= W_b/2240$
Z1(2)	Z_{100A}	= VCG of bottom plating / hull depth = Z_b/H_h
V1(2)	∇_{100A}	= volume of bottom plating in $ft^3 = \nabla_b$
W1(3)	W_{100B}	= weight of plating for hull sides in tons $= W_s/2240$
Z1(3)	Z_{100B}	= VCG of side plating / hull depth = Z_s/H_h
V1(3)	∇_{100B}	= volume of side plating in $ft^3 = \nabla_s$
W1(4)	W_{101}	= weight of framing in tons=$W_{fr}/2240$
Z1(4)	Z_{101}	= VCG of framing / hull depth = Z_{fr}/H_h
V1(4)	∇_{101}	= volume of framing in $ft^3 = \nabla_{fr}$
W1(5)	W_{103A}	= weight of upper platform in tons $= W_{pl_2}/2240$
Z1(5)	Z_{103A}	= VCG of upper platform / hull depth $= Z_{pl_2}/H_h$
V1(5)	∇_{103A}	= volume of upper platform in $ft^3 = \nabla_{pl_2}$
W1(6)	W_{103B}	= weight of lower platform in tons $= W_{pl_1}/2240$

Z1(6)	Z_{103B} = VCG of lower platform / hull depth = Z_{pl_1}/H_h
V1(6)	Z_{103B} = volume of lower platform in ft^3 = ∇_{pl_1}
W1(7)	W_{107} = weight of main deck in tons = $W_d/2240$
Z1(7)	Z_{107} = VCG of main deck / hull depth = Z_d/H_h
V1(7)	∇_{107} = volume of main deck in ft^3 = ∇_d
NTB	n_{tb}' = revised number of transverse bulkheads n_{tb}' = 1, if $\Delta_{LT} \leq 10$ n_{tb}' = $3.663\ \ell_n(\Delta_{LT}/8.1)$, if $10 < \Delta_{LT} < 70$ n_{tb}' = 9, if $\Delta_{LT} \geq 70$
W1(8)	W_{114A} = weight of transverse bulkheads in tons = $\Sigma W_{tb}\ (n_{tb}'/9)/2240$
Z1(8)	Z_{114A} = VCG of transverse bulkheads / hull depth = $\overline{Z}_{tb}/H_h$
V1(8)	∇_{114A} = volume of transverse bulkheads in ft^3 = $\Sigma\nabla_{tb}\ (n_{tb}/9)$
W1(9)	W_{114B} = weight of longitudinal bulkheads in tons = $\Sigma W_{\ell}/2240$
Z1(9)	Z_{114B} = VCG of longitudinal bulkheads / hull depth = $\overline{Z}_{\ell b}/H_h$
V1(9)	∇_{114B} = volume of longitudinal bulkheads in ft^3 = $\Sigma\nabla_{\ell b}$

Subscripts are BSCI 3-digit code

The superstructure, foundations for propulsion and other equipment, and attachment are calculated in Subroutine TOTALS.

NAME:	SUBROUTINE STRUCT (to be used when ILC=1 and IMAT<3)
PURPOSE:	Calculate weight, volumes, and VCG's of major structures, Group 1, for landing craft with well
CALLING SEQUENCE:	CALL STRUCT
INPUT:	Via COMMON blocks
IMAT	IMAT = 1,2 for structures of aluminum or steel, from Card 11
WSFMIN	S_{min} = minimum unit weight of plating in lb/ft^2, from Card 11
WSLOPE	S_P = slope of unit weight curves, from Card 11
DMAT	γ_{mat} = density of structural material in lb/ft^3, from Card 11
XLWELL	L_{well} = length of well deck in ft, excluding aft ramp, from Card 6A
XLBOWR	L_{bow} = length of bow ramp in ft, from Card 6A
BWELL	B_{well} = breadth of well deck in ft, from Card 6A
BBOWR	B_{bow} = breadth of bow ramp in ft, from Card 6A
BAFTR	B_{aft} = breadth of aft (drive through) ramp in ft, from Card 6A
ZWELL	Z_{well} = height of well deck above baseline in ft, from Card 6A
ZAFTR	Z_{aft} = height of aft ramp above baseline in ft, from Card 6A
Other	Hull geometry from Subroutines NEWHUL, NEWVOL, etc.
OUTPUT:	Via COMMON blocks

A. GENERAL EQUATIONS

Same as Subroutine STRUCT for conventional planing hulls.

B. GEOMETRY OF WELL AND RAMPS

XLAFTR	L_{aft} = length of aft ramp in ft = $L_P - L_{well}$
I	Index for DO LOOP I = 1, NN
HWELL(I)	H_{well} = depth from main deck to well deck or aft ramp in ft

$$= Z_S - Z_{well} \text{ if } X > L_{aft}$$
$$= Z_S - Z_{aft} \text{ if } X \le L_{aft}$$

AWELL(I) A_{well} = sectional area below main deck, not enclosed, in ft
= $B_{well} \times H_{well}$ if $X > L_{aft}$
= $B_{aft} \times H_{well}$ if $X \leq L_{aft}$

VOLWE ∇_{well} = volume below main deck, not enclosed, in ft^3
= $\int A_{well}\, dX$

C. PLATFORM DECKS

none

D. TRANSVERSE BULKHEADS

NTB n_{tb} = number of transverse bulkheads input ≤ 15 may be adjusted later so that bulkheads are spaced about 6 ft apart under well deck

J Index for DO LOOP J = 1, NTB

ZKS H_{tb} = height of bulkhead in ft = $Z_S - Z_K$

PRES P_{tb} = design pressure on bulkhead in $lb/in.^2$
= $64\ (H_{tb}+4)/144$
no addition required for fuel tanks

WSF S_{tb} = unit weight of transverse bulkhead, Figure 4

AP A_{tb} = area of transverse bulkhead in ft^2
= $A_S - A_{well}$

DTB D_{tb} = depth of bulkhead web in ft--from general equation

WTB(J) W_{tb} = weight of transverse bulkhead in lb
= $A_{tb} \times S_{tb}$

VTB ∇_{tb} = volume of transverse bulkhead in ft^3
= $A_{tb} \times D_{tb}$

ZTB(J) Z_{tb} = VCG of transverse bulkhead in ft
= $[(A_S \times C_S) - A_{well}(Z_{well}+1/2\ H_{well})]/(A_S - A_{well})$

WTBT $\Sigma\Delta_{tb}$ = total weight of all transverse bulkheads in lb

VTBT $\Sigma\nabla_{tb}$ = total volume of all transverse bulkheads in ft^3

ZTBT $\bar{Z}_{tb}$ = net VCG of all transverse bulkheads in ft
= $\Sigma(W_{tb} \times Z_{tb})/\Sigma W_{tb}$

E. LONGITUDINAL BULKHEADS

NLB	$n_{\ell b}$	= number of longitudinal bulkheads = number of propulsion units $n_{pr} - 1$
		Longitudinal bulkheads extend from transom to aft end of well deck and from bottom of hull up to bottom of aft ramp.
ZKS	$H_{\ell b}$	= mean height of longitudinal bulkheads in ft $\approx Z_{aft} - Z_{K_2}$
PRES	$P_{\ell b}$	= design pressure in lb/in.^{2} = $64(H_{\ell b}+4)/144$
WSF	$S_{\ell b}$	= unit weight in lb/ft^2, Figure 4
ALBT	$\Sigma A_{\ell b}$	= total area of longitudinal bulkheads in ft^2 = $H_{\ell b} \times L_{aft} \times n_{\ell b}$
DLB	$D_{\ell b}$	= depth of longitudinal bulkhead web in ft
WLBT	$\Sigma W_{\ell b}$	= total weight of longitudinal bulkheads in lb = $\Sigma A_{\ell b} \times S_{\ell b}$
VLBT	$\Sigma \nabla_{\ell b}$	= total volume of longitudinal bulkheads in ft^3 = $\Sigma A_{\ell b} \times D_{\ell b}$
ZLBT	$\bar{Z}_{\ell b}$	= net VCG of longitudinal bulkheads in ft = $Z_{K_2} + \frac{1}{2} H_{\ell b}$

F. HULL BOTTOM - KEEL TO CHINE

Same as Subroutine STRUCT for regular planing hull

WBOTT	W_b	= weight of bottom plating in lb
VBOTT	∇_b	= volume of bottom plating in ft^3
ZBOTT	Z_b	= VCG of bottom plating in ft

G. HULL SIDES - CHINE TO MAIN DECK + WALLS OF THE WELL

WSF2	S_{so}	= unit weight of outer side plating, Figure 5
WSFMIN	S_{sw}	= unit weight of plating for well walls = S_{min}
ASIDE	A_{so}	= area of both outer sides in ft^2

$$= 2 \int_0^{L_P} G_{CS}\, dX$$

ASWELL	A_{sw}	= area of both sides of well in ft^2
		$= 2 \int_0^{L_P} H_{well}\, dX$
DSIDE	D_{so}	= depth of side plating web in ft
WSIDE	W_s	= weight of side plating, including well walls, in lb
		$= (A_{so} \times S_{so}) + (A_{sw} \times S_{sw})$
VSIDE	∇_s	= volume of side plating, including well walls, in ft^3
		$= (A_{so} \times D_{so}) + (A_{sw} \times D_{min})$
ZSIDE	Z_s	= VCG of side plating in ft, assumed same as well wall

H. MAIN DECK

PRES	P_d	= design pressure on main deck in lb/in.^{2}
		$= 64 \times 4/144$
WSF3	S_d	= unit weight of main deck, Figure 4
ABWELL	A_{bw}	= area of bottom of well in $ft^2 = L_{well} \times B_{well}$
AAFTR	A_{ba}	= area of bottom of aft ramp in $ft = L_{aft} \times B_{aft}$
ADECK	A_d	= area of main deck in ft^2
		$= 2 \int_0^{L_P} Y_S\, dX - (A_{bw}+A_{ba})$
DDECK	D_d	= depth of main deck web in ft
WDECK	W_d	= weight of main deck in lb $= A_d \times S_d$
VDECK	∇_d	= volume of main deck in $ft^3 = A_d \times D_d$
ZDECK	Z_d	= VCG of main deck in ft

I. STRESS CALCULATION AT MIDSHIPS

Not required for landing craft

J. WELL DECK, INCLUDING AFT DRIVE-THROUGH RAMP

PRES	P_{wd}	= design pressures on well deck in lb/in.^{2}
		= 70.0
WSF4	S_{wd}	= unit weight of well deck, Figure 4

ADECKW	A_{wd}	= area of well deck, including aft ramp, in ft^2 = $A_{bw} + A_{ba}$
DDECKW	D_{wd}	= depth of well deck web in ft
WDECKW	W_{wd}	= weight of well deck in lb = $A_{wd} \times S_{wd}$
VDECKW	∇_{wd}	= volume of well deck in ft^3 = $A_{wd} \times D_{wd}$
ZDECKW	Z_{wd}	= VCG of well deck in ft = $[(A_{bw} \times Z_{well}) + (A_{ba} \times Z_{aft})]/(A_{bw} + A_{ba})$

K. BOW RAMP

WSF	S_{br}	= unit weight of bow ramp in lb/ft^2
		Aluminum hull: S_{br} = 25.0
		Steel hull: S_{br} = 41.3
ABOWR	A_{br}	= area of bow ramp in ft^2 = $L_{bow} \times B_{bow}$
DBOWR	D_{br}	= depth of bow ramp in ft
WBOWR	W_{br}	= weight of bow ramp in lb = $A_{br} \times S_{br}$
VBOWR	∇_{br}	= volume of bow ramp in ft^2 = $A_{br} \times D_{br}$
ZBOWR	Z_{br}	= VCG of bow ramp in ft = $1.4 \times Z_{well}$

L. FRAMING - LONGITUDINAL AND TRANSVERSE

Same as regular planing hull, except that volume of well ∇_{well} is subtracted from hull volume ∇_h

WFRAM	W_{fr}	= total weight of framing in lb, Figure 6 = $f(\nabla_h')$ where $\nabla_h' = \nabla_h - \nabla_{well}$
VFRAM	∇_{fr}	= volume of framing in ft^3 = 0.06 W_{fr} or 0.03 W_{fr} for aluminum or steel
ZFRAM	Z_{fr}	= VCG of framing in ft

M. SUMMARY OF STRUCTURES--Group 1

W1(2)	W_{100A}	= weight of bottom plating in tons = $W_b/2240$
W1(3)	W_{100B}	= weight of side plating, including walls of well, in tons = $W_s/2240$
W1(4)	W_{101}	= weight of framing in tons = $W_{fr}/2240$
W1(5)	W_{107A}	= weight of bow ramp in tons = $W_{br}/2240$
W1(6)	W_{107B}	= weight of well deck, including drive-through ramp, in tons = $W_{wd}/2240$

W1(7)	W_{107C} = weight of main deck in tons = $W_d/2240$
NTB	n'_{tb} = reversed number of transverse bulkheads = $(L_{well}/6.0) + 2$
W1(8)	W_{114A} = weight of transverse bulkheads in tons = $\Sigma W_{tb}\ (n'_{tb}/n_{tb})/2240$
W1(9)	W_{114B} = weight of longitudinal bulkheads in tons = $\Sigma W_{lb}/2240$
Z1 array	VCG/H_h of structural components in same order as W1 array
V1 array	Volume in ft^3 of structural components in same order as W1 and Z1 arrays

The superstructure, foundations, and attachments are calculated in Subroutine TOTALS.

Subscripts are BSCI 3-digit code

NAME:	SUBROUTINE POWER	
PURPOSE:	Estimate power requirements at design and cruise speeds. Calculate weights, volumes, and VCG's of major components of propulsion system, Group 2. Calculate fuel required for range specifications.	
CALLING SEQUENCE:	CALL POWER	
SUBROUTINES CALLED:	PHRES, PRCOEF, SAVIT, PROPS, WJETS	
INPUT:	Via COMMON blocks	
VDES	V_d	= design (maximum) speed in knots, from input Card 7
VCRS	V_c	= cruise speed in knots $\leq V_d$, from Card 7
RANGED	$Range_d$	= range requirement at design speed in nautical miles, from Card 7
	May be 0 if cruise range dominates	
RANGEC	$Range_c$	= range requirement at cruise speed in nautical miles, from Card 7
H13D	$H_{1/3_d}$	= maximum significant wave height in ft specified for operation of ship at V_d, from Card 7
H13C	$H_{1/3_c}$	= maximum significant wave height in ft specified for operation of ship at V_c, from Card 7
IPROP	Control for type of thrusters, from Card 6 IPROP = 1 for Gawn-Burrill type propellers IPROP = 2 for Newton-Rader type propellers IPROP = 3 for Wageningen B-screw type propellers IPROP = 4 for waterjet pumps	
IPM	Control for type of engines, from Card 6 IPM = 1 for diesel prime movers IPM = 2 for gas turbine prime movers IPM = 3 for CODOG system IPM = 4 for COGOG system	
DLBS	Δ	= ship displacement in lb, from Subroutine NEWHUL
PRN	n_{pr}	= number of prime movers = number of thrusters, from input Card 12 or Subroutine PROPS
AUXNO	n_{aux}	= number of auxiliary engines, from Card 12
Other	Various constants relating to engines and gears from input Cards 13, 14, and 15	

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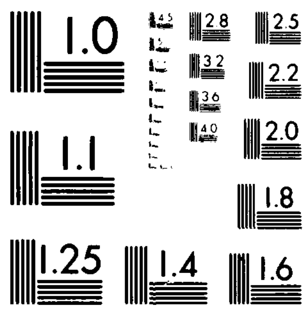

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963 A

OUTPUT:	Via COMMON blocks	

A. POWER REQUIREMENTS AT DESIGN AND CRUISE SPEEDS

NV	Number of speeds = 2 (if $V_c < V_d$) ; 1 (if $V_c = V_d$)	
I	Index for DO LOOP I = 1, NV	
VKT(I)	V_K	= ship speed in knots = V_d, V_c when I = 1,2
VFPS	V	= ship speed in ft/sec = 1.6878 V_K
FNV(I)	$F_{n\nabla}$	= speed-displacement coefficient = $V/(g\nabla^{1/3})^{1/2}$
H13(I)	$H_{1/3}$	= significant wave height in ft
ADF(I)	η_a	= appendage drag factor
TDF(I)	1-t	= thrust deduction factor
TWF(I)	1-w	= thrust wake factor = torque wake factor
	Propellers: η_a, 1-t, 1-w from Subroutine PRCOEF	
	Waterjets: η_a = 1.0; 1-t = 0.95; 1-w = 1.0	
TAU(I)	τ	= trim angle in degrees from Subroutine SAVIT
RWS(I)	$(R/W)_s$	= resistance-weight ratio from Subroutine SAVIT, not used for the power predictions
RWB(I)	$(R/W)_b$	= resistance-weight ratio of bare hull = R_b/Δ
RWA(I)	$(R/W)_a$	= resistance-weight ratio of appendaged hull = R_a/Δ
RWW(I)	$(R/W)_w$	= resistance-weight ratio in seaway = R_T/Δ
RBH	R_b	= bare hull resistance from Subroutine PHRES or input from Card 7 or Card 29
	R_a	= appendaged hull resistance = R_b/η_a
RT	R_T	= total resistance at $H_{1/3}$ = R_a + R_{aw}
	R_{aw}	= added resistance in waves
EHPBH	P_{E_b}	= bare hull effective power = R_b V / 550
EHP(I)	P_E	= total effective power = R_T V / 550
THRUST(I)	T	= total thrust in lb = $R_T/(1-t)$
DHP(I)	P_D	= total power delivered at thrusters

Note: $R_{aw}/\Delta = 1.3\ (H_{1/3}/B_{PX})^{0.5}\ (L_P/\nabla^{1/3})^{-2.5}\ F_{n\nabla}$

SHP(I)	P_S	= total shaft power
RPM(I)	N	= speed of thrusters in revolutions per minute
PC(I)	η_D	= propulsive coefficient = P_E/P_D

For propellers: P_D, P_S, N, η_D from Subroutine PROPS

For waterjets: P_D, P_S, N, η_D from Subroutine WJETS

BHP(I)	P_B	= total brake power
PCO(I)	OPC	= overall performance coefficient = P_{E_b}/P_D
TORQUE(I)	Q	= total torque in ft-lb = $33000\ P_D/(2\pi\ N)$
BHP (1)	P_d	= total brake power at V_d
BHP (2)	P_c	= total brake power at V_c

B. PRIME MOVERS AND GEARS

PE	P_e	= maximum brake power of each prime mover = P_d/n_{pr} or $P_{e_{max}}$ from input Card 12, whichever is smaller
THP	P_d'	= total brake power of prime movers = $P_e \times n_{pr}$
SWE	SW_e	= specific weight of engines in lb/hp

Diesels: $SW_e = FM1\ (25.1/P_e^{0.207})$

Gas Turbines: $SW_e = FM1\ (0.42+2.88\times10^6/P_e^{2.67})$

WE	W_e	= weight of each prime mover in lb = $SW_e \times P_e$

W_e from general equations may be superseded by value of FWE input on Card 15

RE	N_e	= speed of prime movers in rpm

Diesels: $N_e = FM5\ (2.09\times10^4\ P_e^{0.884}/W_e)$

Gas Turbines: $N_e = FM5\ (5.4\times10^5/P_e^{0.49})$

RD	N_d	= speed of thrusters at V_d in rpm
GR	m_g	= gear ratio = N_e/N_d
QE	Q_e	= gear weight factor = $(P_e/N_e)(m_g+1)^3/m_g$

WG	W_g	= weight of gears for each prime mover in lb
		$= 16000\,(Q_e/K)^{0.9}$ for single reduction gears
		$= 9500\,(Q_e/K)$ for planetary gears
	K	= gear tooth factor input on Card 14
	W_g from general equations may be superseded by value of FWG input on Card 15	

C. AUXILIARY ENGINES AND GEARS (By-pass if IPM < 3)

AHP	P_c	= total horsepower of auxiliary engines
		$= P_B$ at V_c
PEA	P_a	= horsepower of each auxiliary engine
		$= P_c/n_{aux}$
SWA	SW_a	= Specific weight of auxiliary engines in lb/hp
	Diesels: $SW_a = FM2\,(25.1/P_a^{0.207})$	
	Gas Turbines: $SW_a = FM2\,(0.42+2.88\times10^6/P_a^{2.67})$	
WEA	W_a	= weight of each auxiliary engine in lb
		$= SW_a \times P_a$
	W_a from general equations may be superseded by value of FWEA input on Card 15	
REA	N_a	= speed of auxiliary engines in rpm
	Diesels: $N_a = FM6\,(2.09\times10^4\,P_a^{0.884}/W_a)$	
	Gas Turbines: $N_a = FM6\,(5.4\times10^5/P_a^{0.49})$	
RC	N_c	= speed of thrusters at V_c in rpm
GRA	m_{g_a}	= gear ratio = N_a/N_c
QE	Q_a	= gear weight factor = $(P_a/N_a)(m_{g_a}+1)^3/m_{g_a}$
WGA	W_{g_a}	= weight of gears for each auxiliary engine in lb
		$= 16000\,(Q_a/K)^{0.9}$ for single reduction gears
		$= 9500\,(Q_a/K)$ for planetary gears
	K	= gear tooth factor input on Card 14
	W_{g_a} from general equations may be superseded by value of FWGA input on Card 15	

D. PROPELLERS, SHAFTING, BEARINGS, ETC. (By-pass if IPROP = 4)

DFT	D	= diameter of propeller in ft from Subroutine PROPS
EAR	EAR	= propeller expanded area ratio input on Card 12
WPR	W_{pr}	= weight of each propeller in lb $= D^3\ (5.05\ \mathbf{EAR} + 3.3)$
SHL	L_{sh}	= shaft length in ft from Subroutine PROPS
QD	Q_{sh}	= torque per shaft in ft-lb = Q at V_d/n_{pr}
	S_s	= shear stress due to torsion in lb/in^2 = 14000
	ζ	= shaft inner diameter/outer diameter initial value of 0.67 used for hollow shaft
SHDO	d_o	= outer shaft diameter in inches $= [192\ Q_{sh}/(\pi S_s)/(1-\zeta^4)]^{1/3}$ If $d_o < 6$ inches, set $\zeta=0$ for solid shaft, and recalculate d_o
SHDI	d_i	= inner shaft diameter in inches = $\zeta\ d_o$
WSH	W_{sh}	= weight of each shaft in lb $= 3.396\ L_{sh}\ (d_o^{\ 2}-d_i)^2\ \pi/4$
	L_{max}	= maximum length of unsupported shafting in ft $= 178.5\ (d_o/N_d)^{1/2}$
NSEG	n_{seg}	= number of shaft segments = L_{sh}/L_{max} rounded up
SEGL	L_{seg}	= length of each segment in ft = L_{sh}/n_{seg}
WB	W_b	= weight of coupling, bearings, etc. for each shaft in lb $= n_{seg}\ (0.00792\ Q_d + 5.0\ d_o\ L_{seg})$

E. WATERJET PUMPS (By-pass if IPROP < 4) SUBROUTINE POWER

DFT	D	= diameter of waterjet impeller in ft from Subroutine WJETS
AJ	A_J	= area of jet in ft^2 from Subroutine WJETS
WJW	B_{wj}	= breadth of each waterjet unit in ft = 1.10 D
WJL	L_{wj}	= length of waterjet unit inside of hull, in ft = 4.8 D
WJH	H_{wj}	= height of waterjet unit in ft = 1.8 D
V2(3)	∇_{wj}	= internal volume required for waterjets in ft^3 $= [n_{pr} B_{wj} + c(1 + n_{pr})] [H_{wj} + c] [L_{wj}]$ where c is clearance of 1.5 ft around units
Z2(3)	VCG_{wj}	= VCG of waterjets above baseline in ft $= Z_{K_1} + 0.5 (Z_{C_1} - Z_{K_1}) + 1.15 D$
HPD	P_d	= maximum input horsepower per unit $= (DHP \text{ at } V_d) / n_{pr}$
WPR	W_{wj}	= weight of each complete waterjet unit in lb* $= 1.4 \rho A_J (b_0 P_d^{e_0} + b_1 P_d^{e_1} + b_2 P_d^{e_2} + b_3 P_d^{e_3})$

where
$b_0 = -695241.$ $e_0 = -1.0556$
$b_1 = 4321.3$ $e_1 = -0.0556$
$b_2 = 1.2156$ $e_2 = 0.9444$
$b_3 = -0.0000395$ $e_3 = 1.9444$

WSH	$W_{sh} = 0$	Weight of shaftings, bearings, etc. included in W_{wj};
WB	$W_b = 0$	Factor of 1.4 in equation for waterjet weight takes care of steering-reversing gear.

F. VOLUME REQUIRED FOR PROPULSION SYSTEM

VOLE — ∇_e = volume of main engine room for prime movers in ft^3

Diesels: $\nabla_e = 31.95\ P_d\ \Delta_{LT}^{0.228}/V_d^{1.37}$

Gas Turbines: $\nabla_e = 0.274\ P_d$

VOLEA — ∇_a = volume of space for auxiliary engines in ft^3

Diesels: $\nabla_a = 31.95\ P_c\ \Delta_{LT}^{0.228}/V_c^{1.37}$

Gas Turbines: $\nabla_a = 0.137\ P_c$

VOLE2 — ∇_{e2} = volume of inlets and exhausts for prime movers in ft^3

Diesels: $\nabla_{e2} = 0.0357\ P_d$

Gas Turbines: $\nabla_{e2} = 0.06135\ P_d$

VOLEA2 — ∇_{a2} = volume of inlets and exhausts for auxiliary engines in ft^3

Diesels: $\nabla_{a2} = 0.0357\ P_c$

Gas Turbines: $\nabla_{a2} = 0.06135\ P_c$

∇_e, ∇_a, ∇_{e2}, ∇_{a2} from general equations above may be superseded by values of FVOLE, FVOLEA, FVOLE2, FVOLA2, respectively, input on Card 15.

Space for all other components of propulsion system assumed to be included in main engine room ∇_e, except for waterjets. See Section D for additional volume required for waterjets.

G. SUMMARY OF PROPULSION--Group 2

W2(2)	W_{201}	= weight of propulsion units, engines and gears in tons $= [(W_e+W_g)\ n_{pr} + (W_a+W_{ga})\ n_{aux}]/2240$
W2(3)	W_{203}	= weight of shafting, bearings, and propellers (or waterjets) in tons $= (W_{sh}+W_b+W_{pr})\ n_{pr}/2240$
W2(4)	$W_{204,205}$	= weight of combustion air supply and uptakes in tons = $0.0002\ P_d$
W2(5)	W_{206}	= weight of propulsion control equipment in tons = $0.00005\ P_d$
W2(6)	W_{209}	= weight of circulating and cooling water system in tons = $0.000036\ P_d$
W2(7)	W_{210}	= weight of fuel oil service system in tons = $0.000076\ P_d + W_{ft}$
W2(8)	W_{211}	= weight of lubricating oil system in tons = $0.000036\ P_d$
W2(9)	$W_{250,251}$	= weight of repair parts and operating fluids in tons = $0.000118\ P_d$
V2(2)	∇_{201}	= volume of propulsion units in ft^3 $= \nabla_e + \nabla_a$
V2(3)	∇_{203}	= 0.0 except when waterjets are used; see section on waterjets
V2(4)	$\nabla_{204,205}$	= volume of air supply and uptakes in ft^3 $\nabla_{e2} + \nabla_{a2}$
VPR	∇_{pr}	= total volume of propulsion system in ft^3 $= \nabla_{201} + \nabla_{203} + \nabla_{204,205}$
	Subscripts are BSCI 3-digit code	
Z2(4)	$Z_{204,205}$	= VCG of air supply and uptakes / hull depth = 1.13

H. FUEL REQUIREMENT

SFCD $\quad SFC_d$ = specific fuel consumption of prime movers at design speed in lb/hp/hr

Diesels:
$$SFC_d = FM3\ [0.859-0.247 \log P_e + 0.0309(\log P_e)^2]$$

Gas Turbines:
$$SFC_d = FM3\ [1.565-0.488 \log P_e + 0.0501\ (\log P_e)^2]$$

SFC_d from general equations may be superseded by value of FSFCD input on Card 15.

SFCC | SFC_c = specific fuel consumption of prime movers at cruise speed in lb/hp/hr (by-pass if auxiliary engines are used)

Diesels: $$SFC_c = SFC_d\ [0.853/(P_c/P_d)^{0.214} + 0.147\ (P_c/P_d)^3]$$

Gas Turbines: $$SFC_c = SFC_d\ [(-0.181\ P_e^{0.11} + 0.762) / (P_c/P_d)^{0.825} + 0.377\ P_e^{0.0734}]$$

SFCC | SFC_c = specific fuel consumption of auxiliary engines with maximum power at V_c in lb/hp/hr

Diesels: $$SFC_c = FM4\ [0.859 - 0.247 \log P_a + 0.0309\ (\log P_a)^2]$$

Gas Turbines: $$SFC_c = FM4\ [1.565 - 0.488 \log P_a + 0.0501\ (\log P_a)^2]$$

SFC_c from general equations may be superseded by value of FSFCC input on Card 15.

FRD | FR_d = total fuel rate in lb/hr at design speed $= SFC_d \times P_d$

FRC | FR_c = total fuel rate at cruise speed in lb/hr $= SFC_c \times P_c$

HOURS | H_c = operating time for cruise speed range in hours $= Range_c/V_c$

HOURSD | H_d = operating time for design speed range in hours $= Range_d/V_d$

WF | W_{f_c} = fuel required for cruise speed range in tons $= H_c \times FR_c/0.95/2240$

WFDES | W_{f_d} = fuel required for design speed range in tons $= H_d \times FR_d/0.95/2240$

WF W_f = weight of fuel in tons

= W_{f_c} or W_{f_c} , whichever is greater

$Range_c$ or $Range_d$ is recalculated based on the dominating fuel weight W_f.

WFT W_{ft} = weight of fuel tanks in tons

If IFT = 0, then W_{ft} = 0, since fuel tanks, are included with the hull structures.

If IFT = 1, then W_{ft} = 0.15 W_f, for separate fuel tanks (1.0 lb / gallon of fuel)

NAME: SUBROUTINE ELECPL

PURPOSE: Calculate weights, volumes, and VCG's of the major components of the electric plant, Group 3

CALLING SEQUENCE: CALL ELECPL

INPUT: Via COMMON blocks

FKW	KW	= electric power in kilowatts, optional input on Card 11
W	W	= total ship weight in tons = Δ_{LT}, from PHFMOPT
HMB	H_{mb}	= height of machinery box in ft, from Subroutine NEWVOL
HDM	H_h	= hull depth at midships in ft, from PHFMOPT
PL	L_P	= ship projected chine length in ft, from input Card 29
BPA	B_{PA}	= average chine beam in ft, from Subroutine NEWHUL
VOLT	∇_T	= total enclosed volume, including superstructure, in ft^3, from Subroutine NEWVOL

OUTPUT: Via COMMON blocks

PKW	KW	= electric power in kilowatts = $4.29 \times W^{0.79}$ or value of FKW input on Card 11
W3(2)	W_{300}	= weight of electric power generation in tons = $0.352 + 0.0408$ KW if KW ≤ 40 = $1.8 + 0.0046$ KW if KW > 40
Z3(2)	Z_{300}	= VCG of electric power generation / hull depth = $(2.0 + 0.63\ H_{mb})\ /\ H_h$
W3(3)	W_{301}	= weight of power distribution switchboard in tons = 0.0033 KW
Z3(3)	Z_{301}	= VCG of power distribution switchboard / hull depth = $0.786\ H_{mb}/H_h$
W3(4)	W_{302}	= weight of power distribution system cables = $0.000085\ \nabla_T$
Z3(4)	Z_{302}	= VCG of power cables / hull depth = 0.699
W3(5)	W_{303}	= weight of lighting system in tons = $0.0000265\ L_P \times B_{PA} \times H_h$
Z3(5)	Z_{303}	= VCG of lighting system / hull depth = 1.383

No volume is added for electric plant assumed to be included in volume of main engine room.

Subscripts are BSCI 3-digit code

NAME:	SUBROUTINE COMCON
PURPOSE:	Calculate weights, volumes, and VCG's of the non-military components of communication and control, Group 4
CALLING SEQUENCE:	CALL COMCON
INPUT:	Via COMMON blocks
VOLT	∇_T = total enclosed volume, including superstructure, in ft^3, from Subroutine NEWBOL
PL	L_P = ship projected chine length in ft, from input Card 29
BPA	B_{PA} = average chine beam in ft, from Subroutine NEWHUL
HDM	H_h = hull depth at midships in ft, from PHFMOPT
ZPC	Z_{PC} = centroid of profile above baseline / hull depth, from Subroutine NEWVOL
OUTPUT:	Via COMMON blocks
W4(2)	W_{400} = weight of non-electronic navigation equipment in tons $= 0.0000035\ \nabla_T$
Z4(2)	Z_{400} = VCG of navigation equipment / hull depth $= 2.18\ Z_{PC}$
V4(2)	∇_{400} = volume of navigation equipment in ft^3 $= 0.10\ \nabla_T$
W4(3)	W_{401} = weight of interior communication system in tons $= 0.0000465\ L_P\ B_{PA}\ H_h$
Z4(3)	Z_{401} = VCG of communication system / hull depth $= 0.786$
V4(3)	∇_{401} = volume of communication system in ft^3 $= 0.0036\ \nabla_T$

Remainder of communication and control is considered part of the payload.

NAME: SUBROUTINE AUXIL

PURPOSE: Calculate weights, volumes, and VCG's of major components of auxiliary systems, Group 5

CALLING SEQUENCE: CALL AUXIL

INPUT: Via COMMON blocks

VOLT	∇_T	= total enclosed volume in ft^3, from Subroutine NEWHUL
PL	L_P	= ship length in ft, from input Card 29
BPA	B_{PA}	= average chine beam in ft, from Subroutine NEWHUL
HMB	H_{mb}	= height of machinery box in ft, from Subroutine NEWVOL
HM	H	= draft at midships in ft, from Subroutine NEWHUL
DMULT	M_Δ	= multiplier for ship size, from Subroutine CREWSS
ZPC	Z_{PC}	= centroid of hull profile above baseline / H_h, from Subroutine NEWVOL
ACC	acc	= total accommodations, from input Card 10 or Subroutine CREWSS
DAYS	days	= number of days for provisions, from Card 10
WF	W_F	= weight of fuel in tons, from Subroutine POWER
W	W	= total ship weight in tons = Δ_{LT} from PHFMOPT

OUTPUT: Via COMMON blocks

A. GENERAL NOTATION

W denotes weight in long tons

Z denotes VCG / hull depth

∇ denotes volume in ft^3

Subscript is BSCI 3-digit code

B. HEATING AND AIR-CONDITIONING SYSTEMS

W5(2)	$W_{500,502}$	$=0.000036\ \nabla_T$
Z5(2)	$Z_{500,502}$	$= 1.271\ Z_{PC}$

C. VENTILATION SYSTEM

W5(3)	W_{501}	$= 0.000025\ \nabla_T$

Z5(3)	Z_{501}	$= 1.528\ Z_{PC}$
V5(3)	∇_{501}	$= 0.03\ \nabla_T$

D. REFRIGERATING SPACES

W5(4)	W_{503}	$= M_{\Delta}\ (0.26 + 0.0113\ \text{acc})$
Z5(4)	Z_{503}	$= 0.465$
V5(4)	∇_{503}	$= 0.69\ \text{acc} \times \text{days}$

E. PLUMBING INSTALLATIONS

W5(5)	W_{505}	$= 0.0267\ \text{acc}$
Z5(5)	Z_{505}	$= 1.29\ Z_{PC}$
V5(5)	∇_{505}	$= 26.4\ \text{acc} + 100.0$

F. FIREMAIN, FLUSHING, SPRINKLING

W5(6)	W_{506}	$= 0.00004\ \nabla_T$
Z5(6)	Z_{506}	$= 0.6689$

G. FIRE EXTINGUISHING SYSTEM

W5(7)	W_{507}	$= 0.0000131\ \nabla_T$
Z5(7)	Z_{507}	$= 0.750$

H. DRAINAGE AND BALLAST

W5(8)	W_{508}	$= 0.0000194\ \nabla_T$
Z5(8)	Z_{508}	$= 0.292$
V5(8)	∇_{508}	$= 0.00438\ \nabla_T$

I. FRESH WATER SYSTEM

W5(9)	W_{509}	$= 0.023\ \text{acc}$
Z5(9)	Z_{509}	$= 1.005\ Z_{PC}$

J. SCUPPERS AND DECK DRAINS

W5(10)	W_{510}	$= 0.00000333\ \nabla_T$
Z5(10)	Z_{510}	$= 0.9806$

K. FUEL AND DIESEL OIL FILLING

W5(11)	W_{511}	$= 0.0003\ W_F$
Z5(11)	Z_{511}	$= 0.418$

L. COMPRESSED AIR SYSTEM

W5(12)	W_{513}	$= 0.0$
Z5(12)	Z_{513}	$= 0.0$

M. DISTILLING PLANT

W5(13)	W_{517}	$= 0.000848\ (15\ \text{acc})^{1.021}$
Z5(13)	Z_{517}	$= 0.540$
V5(13)	∇_{517}	$= H_{mb}\ [160.0 + 0.0031\ (15\ \text{acc})]$

N. STEERING SYSTEMS

W5(14)	W_{518}	$= 0.001205\ H\ L_P$
Z5(14)	Z_{518}	$= 0.656$
V5(14)	∇_{518}	$= 0.2176\ B_{PA}\ L_P$

O. RUDDERS

W5(15)	W_{519}	$= 0.00313\ H\ L_P$
Z5(15)	Z_{519}	$= 0.382$

P. MOORING, TOWING, ANCHOR, DECK MACHINERY

W5(16)	W_{520}	$= 0.00002\ \nabla_T$
Z5(16)	Z_{520}	$= 0.702$
V5(16)	∇_{520}	$= 0.5\ W$

Q. STORES HANDLING

W5(17)	W_{521}	$= 0.00000865\ \nabla_T$
Z5(17)	Z_{521}	$= 1.0$
V5(17)	∇_{521}	$= 0.00088\ \nabla_T$

R. REPLENISHMENT AT SEA

W5(18)	W_{528}	$= 0.0000025\ \nabla_T$
Z5(18)	Z_{528}	$= 0.807$
V5(18)	∇_{528}	$= 0.00168\ \nabla_T$

S. REPAIR PARTS

W5(19)	W_{550}	$= 0.0053\ (W_{500,502}+W_{501}+W_{503}+W_{505}+W_{506}+W_{507}$ $+W_{509}+W_{513}+W_{517}+W_{518}+W_{520})$

Z5(19)	Z_{550}	= 0.5335
V5(19)	∇_{550}	= 0.004 ∇_T

T. OPERATING FLUIDS

W5(20)	W_{551}	= 0.04 (Sum of all preceding Group 5 weights)
Z5(20)	Z_{551}	= 0.9039

Volumes of items not specified are assumed to either be negligible or included in the machinery box.

Weights and volumes from these general equations for the auxiliary systems may be changed or eliminated by appropriate multipliers (K-factors) input on Cards 22 and 23. The multiplications are performed in Subroutine TOTALS together with the summation of all Group 5 weights.

NAME:	SUBROUTINE OUTFIT	
PURPOSE:	Calculate weights, volumes, and VCG's of major components of outfit and furnishings, Group 6	
CALLING SEQUENCE:	CALL OUTFIT	
INPUT:	Via COMMON blocks	
VOLT	∇_T	= total enclosed volume in ft^3, from Subroutine NEWVOL
VPR	∇_{pr}	= total volume of propulsion system in ft^3, from Subroutine POWER
VF	∇_F	= volume of fuel tanks in ft^3, from Subroutine LOADS
PL	L_P	= ship length in ft, from input Card 29
BPA	B_{PA}	= average chine beam in ft, from Subroutine NEWVOL
DMULT	M_Δ	= multiplier for ship size, from Subroutine CREWSS
ZPC	Z_{PC}	= centroid of hull profile above baseline / hull depth, from Subroutine NEWHUL
ACC	acc	= total accommodations, from Card 10 or CREWSS
CREW	crew	= number of enlisted men, from Card 10 or CREWSS
CPO	CPO's	= number of CPO's, from Card 10 or CREWSS
OFF	officers	= number of officers, from Card 10 or CREWSS
OUTPUT:	Via COMMON blocks	

A. GENERAL NOTATION

W denotes weight in long tons

Z denotes VCG / hull depth

∇ denotes volume in ft^3

Subscript is BSCI 3-digit code

B. HULL FITTINGS

W6(2)	W_{600}	$= 0.00034\ L_P\ B_{PA}$
Z6(2)	Z_{600}	$= 1.064$

C. BOATS, STOWAGES, AND HANDLING

W6(3)	W_{601}	$= 0.02232$ acc
Z6(3)	Z_{601}	$= 1.248$

D. RIGGING AND CANVAS

W6(4)	W_{602}	$= 0.005$ (sum of all Group 6 weights)
Z6(4)	Z_{602}	$= 2.15\ Z_{PC}$

E. LADDERS AND GRATING

W6(5)	W_{603}	$= 0.000032\ M_{\Delta}\ (3\ \nabla_{pr} + \nabla_T)$
Z6(5)	Z_{603}	$= 0.469$
V6(5)	∇_{603}	$= 0.10\ M_{\Delta}\ (\nabla_T - \nabla_{pr} - \nabla_F)$

F. NONSTRUCTURAL BULKHEADS AND DOORS

W6(6)	W_{604}	$= 0.0000209\ M_{\Delta}\ \nabla_T$
Z6(6)	Z_{604}	$= 1.438\ Z_{PC}$

G. PAINTING

W6(7)	W_{605}	$= 0.00003348\ \nabla_T$
Z6(7)	Z_{605}	$= 0.958\ Z_{PC}$

H. DECK COVERING

W6(8)	W_{606}	$= 0.0000368\ \nabla_T$
Z6(8)	Z_{606}	$= 1.331\ Z_{PC}$

I. HULL INSULATION

W6(9)	W_{607}	$= 0.00022\ \nabla_T$
Z6(9)	Z_{607}	$= 1.271\ Z_{PC}$

J. STOREROOMS, STOWAGE, AND LOCKERS

W6(10)	W_{608}	$= 0.0688$ acc
Z6(10)	Z_{608}	$= 0.633$
V6(10)	∇_{608}	$= 1.125$ acc

K. EQUIPMENT FOR UTILITY SPACES

W6(11)	W_{609}	$= 0.01$ acc
Z6(11)	Z_{609}	$= 0.728$
V6(11)	∇_{609}	$= 0.552$ acc

L. EQUIPMENT FOR WORKSHOPS

W6(12)	W_{610}	$= 2.0 + 0.000005\ \nabla_T$, if $\nabla_T \geq 300{,}000$
		$= 0.00001165\ \nabla_T$, if $\nabla_T < 300{,}000$

Z6(12)	Z_{610}	$= 1.207\ Z_{PC}$
V6(12)	∇_{610}	$= 8.0\ (100.0 + 0.00025\ \nabla_T)$, if $\nabla_T \geq 300{,}000$
		$= 8.0\ (0.000585\ \nabla_T)$, if $\nabla_T < 300{,}000$

M. GALLEY, PANTRY, SCULLERY, COMMISSARY

W6(13)	W_{611}	= 0.01833 acc
Z6(13)	Z_{611}	$= 1.45\ Z_{PC}$
V6(13)	∇_{611}	= 29.6 acc

N. LIVING SPACES

W6(14)	W_{612}	= 0.03693 (Crew + 1.55 CPO's + 4.35 officers) + 0.00529 (Crew + 4.17 CPO's + 6.36 officers)
Z6(14)	Z_{612}	$= 1.32\ Z_{PC}$
V6(14)	∇_{612}	= 8.0 [19.8 (Crew + 1.55 CPO's + 2.75 officers) + 140.0 + 4.46 (Crew + 3.36 CPO's + 4.68 officers)]

O. OFFICERS, CONTROL CENTER

W6(15)	W_{613}	= 0.02 acc
Z6(15)	Z_{613}	$= 1.538\ Z_{PC}$
V6(15)	∇_{613}	$= 149.3\ W_{613}$

P. MEDICAL - DENTAL SPACES

W6(16)	W_{614}	= 0.0035 acc
Z6(16)	Z_{614}	$= 1.38\ Z_{PC}$
V6(16)	∇_{614}	$= 149.3\ W_{614}$

Volumes of items not specified are assumed to be negligible.

Weights and volumes from these general equations for the outfit and furnishings will be multiplied by appropriate K-factors input on Cards 24 and 25. These multiplications and summations of all Group 6 weights are performed in Subroutine TOTALS.

NAME:	SUBROUTINE LOADS
PURPOSE:	Calculate weights, volumes, and VCG's of the fuel load, crew and effects, personnel stores, and potable water
CALLING SEQUENCE:	CALL LOADS
INPUT:	Via COMMON blocks
WF	W_F = weight of fuel in tons to meet range requirement(s), from Subroutine POWER
HDM	H_h = hull depth at midships in ft, from PHFMOPT
ACC	acc = total accommodations, from Card 10 or Subroutine CREWSS
DAYS	days = number of days for provisions, from Card 10
XL array	K-factors for the loads, from card 16
OUTPUT:	Via COMMON blocks
WL(2)	W_F = weight of fuel in tons
ZL(2)	Z_F = VCG of fuel / hull depth, see Figure 2
	Z_F = centroid of midship section C_{S_m}/H_h if $H_h \leq 10.0$
	Z_F = $(H_h-8.0)/H_h$ if $10.0 < H_h \leq 20.0$
	Z_F = $(H_h-16.0)/H_h$ if $H_h > 20.0$
VL(2)	∇_F = volume of fuel in ft^3 = $42.96 \times W_F \times 1.05$
WL(3)	W_{L1} = weight of crew and personnel effects in tons = $0.120 \times \text{acc}$
ZL(3)	Z_{L1} = VCG of crew and effects / hull depth = 0.732
VL(3)	∇_{L1} = volume of crew and effects in ft^3 = $0.344 \times \text{acc}$
WL(4)	W_{L6} = weight of personnel stores in tons = $0.00284 \times \text{acc} \times \text{days}$
ZL(4)	Z_{L6} = VCG of personnel stores / hull depth = 0.536
VL(4)	∇_{L6} = volume of personnel stores in ft^3 = $(1.05\times\text{acc}\times\text{days}) + (0.265\times\text{acc}^{1/2}\times\text{days}) + (4.38\times\text{acc}^{1/2}\times\text{days}^{1/2}) + (0.4\times\text{days}) + 8.0$
WL(5)	W_{L12} = weight of potable water in tons = $0.1485 \times \text{acc}$ (40 gal per man)
ZL(5)	Z_{L12} = VCG of potable water / hull depth = 0.138

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VL(5) ∇_{L12} = volume of potable water in ft^3 = 5.35 × acc

Weights and volumes of loads from the preceding general equations are multiplied by appropriate K-factors input on Card 16. Normally the K values are 1.0. VCG's are not affected by the multipliers.

WCE W_{CE} = total weight of crew and provisions in tons

$= W_{L1} + W_{L6} + W_{L12}$

ZCE Z_{CE} = net VCG of crew and provisions / hull depth

$$= (W_{L1}Z_{L1} + W_{L6}Z_{L6} + W_{L12}Z_{L12}) / (W_{L1} + W_{L6} + W_{L12})$$

VCE ∇_{CE} = volume of crew and provision in ft^3

$= \nabla_{L1} + \nabla_{L6} + \nabla_{L12}$

NAME:	SUBROUTINE TOTALS
PURPOSE:	Calculate remaining weights for Groups 1 through 6 and apply multipliers from input Cards 17 through 25. Calculate margins and totals for each weight group. Calculate weight, volume, and VCG of the resultant useful load and the payload.
CALLING SEQUENCE:	CALL TOTALS
INPUT:	Via COMMON blocks

W	W_T	= total ship weight, full load, in tons = Δ_{LT} from PHFMOPT
VOLT	∇_T	= total volume of ship, including superstructure, in ft^3, from Subroutine NEWVOL
KG	$\overline{KG}$	= net VCG of ship in ft, from Subroutine NEWHUL
HDM	H_h	= hull depth at midships in ft, from PHFMOPT
HMB	H_{mb}	= height of machinery box in ft, from Subroutine NEWVOL
ZPC	Z_{PC}	= centroid of hull profile above baseline / H_h, from Subroutine NEWVOL
ZSS	Z_{ss}	= VCG of superstructure / H_h, from Subroutine NEWVOL
VOLSS	∇_{ss}	= volume enclosed by superstructure in ft^3, from input Card 10 or Subroutine CREWSS

W1 array Z1 array V1 array	Weight in tons VCG's / hull depth Volumes in ft^3	Structural components, Group 1, from Subroutine STRUCT
W2 array Z2 array V2 array	Weight in tons VCG's / hull depth Volumes in ft^3	Propulsion components, Group 2, from Subroutine POWER
W3 array Z3 array V3 array	Weight in tons VCG's / hull depth Volumes in ft^3	Electric plant components, Group 3, from Subroutine ELECPL
W4 array Z4 array V4 array	Weight in tons VCG's / hull depth Volumes in ft^3	Non-military communication and control components, Group 4 from Subroutine COMCON
W5 array Z5 array V5 array	Weight in tons VCG's / hull depth Volumes in ft^3	Auxiliary systems, Group 5, from Subroutine AUXIL

W6 array	Weight in tons	Outfit and furnishings, Group 6, from Subroutine OUTFIT
Z6 array	VCG's / hull depth	
V6 array	Volumes in ft^3	
X1 array	Group 1	K-factors for each BSCI 3-digit group from input Cards 17 through 25. Weights and volumes from the general equations will be multiplied by the corresponding K-factor
X2 array	Group 2	
X3 array	Group 3	
X4 array	Group 4	
X5 array	Group 5	
X6 array	Group 6	
WF	Weight in tons	fuel load, from Subroutine LOADS
ZF	VCG's / hull depth	
VF	Volume in ft^3	
WCE	Weight in tons	total of crew and effects, personnel stores, and potable water from Subroutine LOADS
ZCE	VCG's / hull depth	
VCE	Volume in ft^3	

OUTPUT: Via COMMON blocks

A. PROPULSION--Group 2

Z2(2) etc. — $Z_{201} = Z_{206} = Z_{209} = Z_{210} = Z_{211} = Z_{250,251}$
= VCG of machinery box / hull depth = 0.615 H_{mb}

Z2(3) — Z_{203} = VCG of shafting, bearings, and propellers / hull depth
= 0.0, propellers assumed at baseline, if IPROP < 3
= VCG of waterjets / H_h, if IPROP = 3

L — Index for DO LOOP L = 2,9

W2(L) — Weights in tons of propulsion components from general equations in Subroutine POWER multiplied by corresponding K-factors from input Card 19

Z2(L) — VCG's / hull depth of propulsion components from general equations. Not affected by K-factors

V2(L) — Volumes in ft^3 of propulsion components from general equations multiplied by corresponding K-factors

W2(10) — W_{2m} = weight margin for propulsion in tons
= $(K_2 - 1.0)$ (sum of weights of propulsion components)

Z2(10) — Z_{2m} = VCG of margin / hull depth
= net VCG ratio of all propulsion components

V2(10) — V_{2m} = volume margin for propulsion = 0.0

W2(1)	W_2	= total weight of propulsion, including margin, in tons
Z2(1)	Z_2	= net VCG of propulsion / hull depth
V2(1)	∇_2	= total volume of propulsion in ft^3

B. ELECTRIC PLANT--Group 3

L		Index for DO LOOP L = 2,5
W3(L) Z3(L) V3(L)		Weight in tons, VCG's / hull depth, volumes in ft^3 of electric plant components. Weights and volumes from general equations multiplied by K-factors from Card 20
W3(6)	W_{3m}	= weight margin for electric plant in tons = $(K_3 - 1.0)$ (Sum of weights of electric plant components)
Z3(6)	Z_{3m}	= VCG of margin / hull depth = net of all components
V3(6)	∇_{3m}	= volume margin for electric plant in $ft^3 = 0.0$
W3(1)	W_3	= total weight of electric plant, including margin in tons
Z3(1)	Z_3	= net VCG of electric plant / hull depth
V3(1)	∇_3	= total volume of electric plant in ft^3

C. COMMUNICATION AND CONTROL--Group 4 (Non-military)

L		Index for DO LOOP L = 2,3
W4(L) Z4(L) V4(L)		Weight in tons, VCG's / hull depth, volumes in ft^3 of non-military communication and control components. Weights and volumes multiplied by K-factors from Card 21
W4(4)	W_{4m}	= weight margin in tons = $(K_4 - 1.0)$ (Sum of non-military weight components)
Z4(4)	Z_{4m}	= VCG of margin / hull depth = net of components
V4(4)	∇_{4m}	= volume margin = 0.0
W4(1)	W_4	= total weight of non-military communication and control, including margin in tons
Z4(1)	Z_4	= net VCG / hull depth
V4(1)	∇_4	= total volume in ft^3

D. AUXILIARY SYSTEMS--Group 5

L	Index for DO LOOP L = 2,20
W5(L) Z5(L) V5(L)	Weight in tons, VCG's / hull depth, volumes in ft^3 of auxiliary systems. Weights and volumes from general equations multiplied by K-factors from Cards 22 and 23
W5(21)	W_{5m} = weight margin in tons = $(K_5 - 1.0)$ (Sum of all auxiliary system weights)
Z5(21)	Z_{5m} = VCG of margin / hull depth = net of components
V5(21)	∇_{5m} = volume margin in ft^3 = 0.06 (Sum of all auxiliary system volumes)
W5(1)	W_5 = total weight of auxiliary systems, including margin, in tons
Z5(1)	Z_5 = net VCG of auxiliary systems / hull depth
V5(1)	∇_5 = total volume of auxiliary system, including margin, in ft^3

E. OUTFIT AND FURNISHINGS--Group 6

L	Index for DO LOOP L = 2,16
W6(L) Z6(L) V6(L)	Weight in tons, VCG's / hull depth, volumes in ft^3 of outfit and furnishings. Weight and volumes multiplied by K-factors from Cards 24 and 25
W6(17)	W_{6m} = weight margin in tons = $(K_6 - 1.0)$ (Sum of all outfit and furnishings weight)
Z6(17)	Z_{6m} = VCG of margin / hull depth = net of components
V6(17)	∇_{6m} = volume margin in ft^3 = 0.06 (Sum of all outfit and furnishings volume)
W6(1)	W_6 = total weight of outfit and furnishings, including margin, in tons
Z6(1)	Z_6 = net VCG of outfit and furnishings / hull depth
V6(1)	∇_6 = total volume of outfit and furnishings, including margin, in ft^3

F. STRUCTURES--Group 1

W1(10) W_{111} = Weight of superstructure in tons = ∇_{ss} /2240

Z1(10) Z_{111} = VCG of superstructure / hull depth = Z_{ss}

V1(10) ∇_{111} = volume of structural materials for superstructure, assumed negligible

W1(11) W_{112} = weight of foundations for propulsion plant in tons, Figure 7

Aluminum Hull $\begin{cases} W_{112} = 0.04911\ W_2 & \text{, if } W_2 \leq 10.0 \\ W_{112} = 0.1785 + 0.03125\ W_2, & \text{if } W_2 > 10.0 \end{cases}$

Steel or GRP $\begin{cases} W_{112} = 0.06371\ W_2 & \text{, if } W_2 \leq 5.5 \\ W_{112} = 0.1785 + 0.03125\ W_2, & \text{if } W_2 > 5.5 \end{cases}$

Z1(11) Z_{112} = VCG of propulsion plant foundation / hull depth = 0.15

V1(11) ∇_{112} = volume of propulsion foundations, assumed negligible

W1(12) W_{113} = weight of foundations for auxiliary and other equipment in tons, Figure 8

Aluminum hull: $W_{113} = 0.03884\ W_A$ $(W_A = W_3 + W_5 + W_6)$

Steel or GRP hull $\begin{cases} W_{113} = 0.05179\ W_A, & \text{if } W_A \leq 10.0 \\ W_{113} = 0.1295 + 0.03884\ W_A, & \text{if } W_A > 10.0 \end{cases}$

Z1(12) Z_{113} = VCG of other foundations / hull depth = 0.78

V1(12) ∇_{113} = volume of other foundations, assumed negligible

W1(13) W_{att} = weight of attachments in tons

Aluminum or Steel: W_{att} = 0.05 x total structures

GRP hulls: W_{att} = 0.02 x total structures

Z1(13) Z_{att} = VCG of attachment / hull depth = net of other components

V1(13) ∇_{att} = volume of attachments, assumed negligible

The attachments, which encompass several BSCI codes, are arbitrarily designated 198 in this program.

L		Index for DO LOOP L = 2,13
W1(L) Z1(L) V1(L)		Weight in tons, VCG's / hull depth, volumes in ft^3 of structural components. Weights and volumes from general equations multiplied by K-factors from Cards 17 and 18
W1(14)	W_{1m}	= weight margin for structures in tons = $(K_1 - 1.0)$ (Sum of weights of structural components)
Z1(14)	Z_{1m}	= VCG of margin / hull depth = net of components
V1(14)	∇_{1m}	= volume margin for structures = 0.0
W1(1)	W_1	= total weight of structures, including margin, in tons
Z1(1)	Z_1	= net VCG of structures / hull depth
V1(1)	∇_1	= total volume of structures in ft^3

G. EMPTY SHIP

WE1	W_E	= weight of empty ship, less fixed payload items, in tons $= W_1 + W_2 + W_3 + W_4 + W_5 + W_6$
ZE1	Z_E	= VCG of empty ship / hull depth $= (W_1Z_1 + W_2Z_2 + W_3Z_3 + W_4Z_4 + W_5Z_5 + W_6Z_6)/W_E$
VE1	∇_E	= volume of empty ship in ft^3 $\nabla_1 + \nabla_2 + \nabla_3 + \nabla_4 + \nabla_5 + \nabla_6$

H. MOMENTS

ZKG	Z_T	= VCG of total ship weight / hull depth $= \overline{KG} / H_h$
WZKG	W_TZ_T	= total weight moment
WZE1	W_EZ_E	= empty ship weight moment

I. USEFUL LOADS

WU =	W_U	= useful load in tons = $W_T - W_E$
WL(1)		= total of fuel, crew and effects, personnel store, potable water, and payload

ZU = ZL(1)	Z_U = VCG of useful load / hull depth $= (W_T Z_T - W_E Z_E)/(W_T - W_E)$
VU = VL(1)	∇_U = volume of useful load in ft^3 $= \nabla_T - \nabla_E$

J. PAYLOAD

WP = WL(6)	W_P = weight of payload in tons $= W_U - W_F - W_{CE}$
ZP = ZL(6)	Z_P = VCG of payload / hull depth $= (W_T Z_T - W_E Z_E - W_F Z_F - W_{CE} Z_{CE}) / W_P$
VP = VL(6)	∇_P = volume of payload in ft^3 $= \nabla_U - \nabla_F - \nabla_{CE}$

Payload includes the armament, Group 7, the military portion of communication and control, Group 4, and ammunition loads in addition to any special loads required for the ship's mission, such as the tanks carried by a landing craft.

This program does not break down the payload into its various components.

K. WEIGHT FRACTIONS

R(1)	W_1 / W_T
R(2)	W_2 / W_T
R(3)	W_3 / W_T
R(4)	W_4 / W_T
R(5)	W_5 / W_T
R(6)	W_6 / W_T
R(7)	W_E / W_T
R(8)	W_U / W_T
R(9)	W_{CE} / W_T
R(10)	W_F / W_T
R(11)	W_P / W_T

L. VCG / HULL DEPTH RATIOS

G(1)	Z_1
G(2)	Z_2
G(3)	Z_3
G(4)	Z_4
G(5)	Z_5
G(6)	Z_6
G(7)	Z_E
G(8)	Z_U
G(9)	Z_{CE}
G(10)	Z_F
G(11)	Z_P

M. VOLUME FRACTIONS

S(1)	∇_1 / ∇_T
S(2)	∇_2 / ∇_T
S(3)	∇_3 / ∇_T
S(4)	∇_4 / ∇_T
S(5)	∇_5 / ∇_T
S(6)	∇_6 / ∇_T
S(7)	∇_E / ∇_T
S(8)	∇_U / ∇_T
S(9)	∇_{CE} / ∇_T
S(10)	∇_F / ∇_T
S(11)	∇_P / ∇_T

NAME:	SUBROUTINE COSTS
PURPOSE:	Estimate base cost of ship by major weight groups. Also estimate life costs of ship
CALLING SEQUENCE:	CALL COSTS
INPUT:	Via COMMON blocks
CKN array	Cost factors for weight Groups 1 through 6 and payload input on Card 26
OPHRS	Operating hours per month, from input Card 27
OPYRS	Total vehicle operating years, from Card 27
XUNITS	Number of vehicles to be built, from Card 27
TIMED	Portion of time operating at maximum speed, from Card 27
TIMEC	Portion of time operating at cruise speed, from Card 27
FUELR	Cost of fuel in dollars per ton, from Card 27
OUTPUT:	Via COMMON blocks
C(1)	C_1 = cost of structures
C(2)	C_2 = cost of propulsion
C(3)	C_3 = cost of electric plant
C(4)	C_4 = cost of non-military communication and control
C(5)	C_5 = cost of auxiliary systems
C(6)	C_6 = cost of outfit and furnishings
C(7)	C_7 = cost of empty ship = $C_1 + C_2 + C_3 + C_4 + C_5 + C_6$
C(8)	C_8 = cost of payload
C(9)	C_9 = base cost of first unit = $C_7 + C_8$
C(10)	C_{10} = average cost of XUNITS
C(11)	C_{11} = life cost of personnel pay and allowances
C(12)	C_{12} = life cost of maintenance
C(13)	C_{13} = life cost of operations, except energy
C(14)	C_{14} = life cost of major support
C(15)	C_{15} = life cost of fuel
C(16)	C_{16} = total life cost = $C_{10} + C_{11} + C_{12} + C_{13} + C_{14} + C_{15}$
	Cost estimates are in millions of FY 77 dollars.

SUBROUTINE COSTS

The cost equations used are based on statistics developed under the ANCVE project and are not for public release.

Cost data from this program should be used only for comparative purposes, i.e., percentage change from some parent configuration, and not as absolute cost figures.

NAME:	SUBROUTINE PHRES
PURPOSE:	Estimate the bare-hull, smooth-water resistance of a hard-chine planing hull from synthesis of Series 62 and 65 experimental data
CALLING SEQUENCE:	CALL PHRES (DLBS, FNV, SLR, DCF, SDF, RLBS)
SUBPROGRAMS CALLED:	DISCOT, YINTX, C1DSF

INPUT:

DLBS	Δ	= ship displacement in lb
FNV	$F_{n\nabla}$	= speed-displacement coefficient $V/(g\nabla^{1/3})^{1/2}$
SLR	$L_p/\nabla^{1/3}$	= slenderness ratio
DCF	C_A	= correlation allowance; may be 0
SDF	Standard deviation factor SDF = 0.0 corresponds to mean resistance-weight R/W curves derived from Series 62 and 65 data SDF = 1.645 corresponds to minimum R/W curves SDF can be used to approximate the resistance curves for a particular hull form	

OUTPUT:

RLBS	R_b	= bare-hull, smooth-water resistance in lb = Δ(mean R/W - SDF $\times$ σ)
	σ	= standard deviation of Series 62-65 data from mean R/W

PROCEDURE:

XFNV array	Tabulated values of $F_{n\nabla}$ from 0.0 to 4.0
ZSLR array	Tabulated values of $L_p/\nabla^{1/3}$ from 4.0 to 10.0
YRWM matrix	Tabulated values of mean R/W as f($F_{n\nabla}$, $L_p/\nabla^{1/3}$) for 100,000-lb planing craft derived from Series 62 and 65 experimental data. See Table 1 and Figure 9
YWSR matrix	Tabulated values of mean wetted area coefficients $S/\nabla^{2/3}$ from Series 62 and 65 hulls. See Table 2 and Figure 10
SD array	Tabulated values of standard deviation σ as f($F_{n\nabla}$) See Table 1 and Figure 9
RWM	R/W for 100,000-lb planing craft interpolated from YRWM matrix of mean R/W values at input $F_{n\nabla}$ and $L_p/\nabla^{1/3}$

WSR		$S/\nabla^{2/3}$ interpolated from YWSR matrix at input $F_{n\nabla}$ and $L_p/\nabla^{1/3}$
		Subroutine DISCOT used for the double interpolation
SDM		σ interpolated from SD array at input $F_{n\nabla}$
		Function YINTX used for single interpolation
RWM	$(R/W)_m$	= corrected R/W for 100,000-lb planing craft = (mean R/W interpolated) - (SDF × σ interpolated)
DLBM	Δ_m	= displacement of 100,000-lb planing craft
XL	λ	= linear ratio of actual ship to 100,000-lb craft = $(\Delta/\Delta_m)^{1/3}$
VFPSM	V_m	= speed of 100,000-lb craft in ft/sec = 19.32 (input $F_{n\nabla}$)
VFPSS	V_s	= speed of actual ship in ft/sec = $V_m\ \lambda^{1/2}$
PLM	L_m	= length of 100,000-lb craft in ft = 11.6014 (input $L_p/\nabla^{1/3}$)
PLS	L_s	= length of actual ship in ft = $L_m\ \lambda$
REM	R_{n_m}	= Reynolds number of 100,000-lb craft = $V_m\ L_m/\nu_m$
RES	R_{n_s}	= Reynolds number of actual ship = $V_s\ L_s/\nu_s$
CFM	C_{F_m}	= Schoenherr frictional resistance coefficient for 100,000-lb craft
CFS	C_{F_s}	= Schoenherr frictional resistance coefficient for actual ship
		Function C1DSF used to obtain Schoenherr frictional resistance coefficients
SM	S_m	= wetted area of 100,000-lb craft in ft^2 = 134.5925 $S/\nabla^{2/3}$
SS	S_s	= wetted area of actual ship in ft^2 = $S_m\ \lambda^2$
RM	R_m	= resistance of 100,000-lb craft in lb = $(R/W)_m\ \Delta_m$

CTM	C_{T_m}	= total resistance coefficient of 100,000-lb craft
		$= R_m/(V_m^2\ S_m\ \rho_m/2)$
CR	C_R	= residual resistance coefficient = $C_{T_m} - C_{F_m}$
CTS	C_{T_s}	= total resistance coefficient of actual ship
		$= C_{F_s} + C_R + C_A$
RLBS	R_b	= resistance of actual ship in lb
		$= C_{T_s}\ V_s^2\ S_s\ \rho_s/2$
VIS	ν_s	= kinematic viscosity for actual ship, input via COMMON
VISM	ν_m	= kinematic viscosity for tabulated data = 1.2817×10^{-5}
RHO2	$\rho_s/2$	= 1/2 water density for actual ship, input via COMMON
RHO2M	$\rho_m/2$	= 1/2 water density for tabulated data = 1.9905/2

TABLE 1 - MEAN VALUES OF RESISTANCE/WEIGHT RATIOS FOR 100,000-POUNDS PLANING CRAFT

From Series 62 and 65 Experimental Data Published in NSRDC Report 4307 with LCG Ranging from 1/3 to 1/2 L_p Forward of Transom

SPEED (KNOTS)	$F_{n\nabla}$	L_p(FT) 46.4	52.2	58.0	63.8	69.6	75.4	81.2	87.0	92.8	104.4	116.0	Standard Deviation σ
		$L_p/\nabla^{1/3}$ 4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	9.0	10.0	
0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5.72	0.50	0.0120	0.0100	0.0085	0.0075	0.0070	0.0065	0.0060	0.0057	0.0055	0.0050	0.0045	0.0065
8.59	0.75	0.0420	0.0345	0.0280	0.0235	0.0200	0.0170	0.0150	0.0135	0.0125	0.0110	0.0100	0.0080
11.45	1.00	0.1050	0.0875	0.0715	0.0580	0.0480	0.0405	0.0350	0.0305	0.0270	0.0220	0.0190	0.0089
14.31	1.25	0.1800	0.1420	0.1140	0.0940	0.0795	0.0675	0.0585	0.0510	0.0450	0.0360	0.0305	0.0095
17.17	1.50	0.1980	0.1550	0.1255	0.1065	0.0930	0.0815	0.0730	0.0660	0.0600	0.0500	0.0425	0.0100
20.03	1.75	0.1995	0.1602	0.1350	0.1165	0.1025	0.0910	0.0820	0.0755	0.0700	0.0610	0.0530	0.0106
22.89	2.00	0.1900	0.1630	0.1430	0.1275	0.1135	0.1020	0.0930	0.0855	0.0795	0.0705	0.0630	0.0112
25.76	2.25	0.1775	0.1642	0.1505	0.1375	0.1260	0.1150	0.1060	0.0985	0.0915	0.0815	0.0745	0.0121
28.62	2.50	0.1690	0.1645	0.1575	0.1475	0.1375	0.1280	0.1200	0.1125	0.1060	0.0950	0.0880	0.0132
31.48	2.75		0.1620	0.1610	0.1550	0.1480	0.1405	0.1330	0.1270	0.1210	0.1110	0.1040	0.0148
34.34	3.00			0.1610	0.1590	0.1565	0.1520	0.1465	0.1415	0.1365	0.1280	0.1205	0.0170
37.20	3.25				0.1590	0.1595	0.1600	0.1585	0.1560	0.1530	0.1465	0.1400	0.0199
40.06	3.50					0.1610	0.1665	0.1695	0.1700	0.1700	0.1670	0.1620	0.0231
42.93	3.75						0.1735	0.1795	0.1825	0.1840	0.1850	0.1830	0.0266
45.79	4.00							0.1890	0.1930	0.1960	0.2005	0.2030	0.0300

TABLE 2 - MEAN VALUES OF WETTED AREA COEFFICIENT $S/\nabla^{2/3}$ FOR PLANING HULLS

From Series 62 and 65 Experimental Data Published in NSRDC Report 4307
with LCG Ranging from 1/3 to 1/2 L_p Forward of Transom

$F_{n\nabla}$	$L_p/\nabla^{1/3}$ 4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	9.0	10.0
0.00	5.80	6.15	6.50	6.85	7.20	7.55	7.90	8.25	8.60	9.30	10.00
0.50	5.95	6.33	6.70	7.07	7.43	7.77	8.09	8.42	8.75	9.42	10.10
0.75	5.99	6.38	6.77	7.15	7.50	7.85	8.18	8.50	8.82	9.48	10.15
1.00	5.99	6.40	6.80	7.20	7.57	7.90	8.23	8.56	8.88	9.54	10.21
1.25	5.92	6.37	6.80	7.22	7.60	7.93	8.27	8.61	8.93	9.60	10.28
1.50	5.76	6.29	6.78	7.21	7.60	7.95	8.30	8.65	8.97	9.65	10.34
1.75	5.51	6.16	6.72	7.17	7.59	7.94	8.29	8.67	9.00	9.70	10.41
2.00	5.20	5.97	6.59	7.08	7.54	7.92	8.27	8.65	9.01	9.75	10.48
2.25	4.76	5.70	6.41	6.97	7.46	7.85	8.23	8.62	9.01	9.78	10.55
2.50	4.20	5.37	6.18	6.81	7.35	7.75	8.15	8.56	8.99	9.80	10.62
2.75		4.95	5.89	6.60	7.17	7.61	8.04	8.48	8.94	9.80	10.68
3.00			5.55	6.35	6.94	7.42	7.89	8.37	8.85	9.79	10.75
3.25				6.06	6.65	7.17	7.68	8.21	8.73	9.76	10.80
3.50					6.30	6.87	7.43	8.01	8.58	9.71	10.85
3.75						6.53	7.10	7.75	8.37	9.62	10.88
4.00							6.70	7.40	8.10	9.50	10.90

NAME:	SUBROUTINE SAVIT	
PURPOSE:	Estimate the bare-hull, smooth-water resistance and trim for a hard-chine planing hull using Savitsky's equations for prismatic planing surfaces	
CALLING SEQUENCE:	CALL SAVIT (DISPL, LCG, VCG, VFPS, BEAM, BETA, TANB, COSB, SINB, HW, WDCST, RHO, VIS, AG, DELCF, R, TD, NT, CLM, GDB)	
SUBPROGRAM CALLED:	C1DSF	

INPUT:

DISPL	Δ	= ship displacement in lb
LCG	$\overline{AG}$	= distance of center of gravity transom in ft
VCG	$\overline{KG}$	= distance of
VFPS	V	= speed in ft/sec
BEAM	b	= beam in ft = maximum chine beam B_{PX} in Program PHFMOPT
BETA	β	= deadrise angle in degrees = deadrise at midships β_m in Program PHFMOPT
TANB	tan β	
COSB	cos β	
SINB	sin β	
HW	H_W	= height of center of wind drag above baseline in ft
WDCST	C_{D_W}'	= horizontal wind force in lb / V^2 = 0.0 in Program PHFMOPT; wind drag neglected
RHO	ρ	= water density in lb × sec^2/ft^4
VIS	ν	= kinematic viscosity of water in ft^2/sec
AG	g	= acceleration of gravity in ft/sec^2
DELCF	C_A	= correlation allowance; may be 0

OUTPUT:

R	R_b	= bare hull, smooth-water resistance in lb
TD	τ	= trim angle in degrees
NT	Number of iterations to obtain trim angle	
CLM	λ	= mean wetted length-beam ratio L_m/b not used by Program PHFMOPT

GDB $\overline{AP}$ = longitudinal center of pressure, distance forward of transom, in ft
not used by Program PHFMOPT

PROCEDURE:

TD τ = trim angle of planing surface from horizontal in deg
first approximation of τ = 4 deg

CV C_V = speed coefficient = $V/(gb)^{1/2}$

CLM λ = mean wetted length-beam ratio
$= L_m/b = (L_K + L_C)/2b$

CLO C_{L_o} = lift coefficient for flat surface
$= \tau^{1.1}\ (0.012\ \lambda^{1/2} + 0.0055\ \lambda^{5/2}/C_V{}^2)$

CLB C_{L_β} = lift coefficient for deadrise surface
$= \Delta/[V^2\ b^2\ \rho/2] = C_{L_o} - 0.0065\ C_{L_o}{}^{0.6}$

C_{L_o} and λ obtained by Newton-Raphson iteration

first approximations: $C_{L_o} = 0.085;\ \lambda = 1.5$

XK L_K = *wetted keel length in ft*
$= b[\lambda + \tan\beta/(2\pi \tan\tau)]$

XC L_C = wetted chine length in ft = $2\ b\ \lambda - L_K$

$L_K - L_C = (b \tan\beta)/(\pi \tan\tau)$

GDB $\overline{AP}$ = longitudinal center of pressure forward of transom in ft
$= b\ \lambda[0.75 - 1/(5.21\ C_V{}^2/\lambda^2 + 2.39)]$

CLD C_{L_d} = dynamic component of lift coefficient
$= 0.012\ \lambda^{1/2}\ \tau^{1.1}$

VM V_m = mean velocity over planing surface in ft/sec
$$= V\left[1 - \left(C_{L_d} - 0.0065\ \beta\ C_{L_d}{}^{0.6}\right)\Big/\left(\lambda \cos\tau\right)\right]^{1/2}$$

RE R_n = Reynolds number for planing surface
$= V_m\ b\ \lambda/\nu$

CF $C_F + C_A$ = Schoenherr frictional resistance coefficient as $f(R_n)$ plus correction allowance

DFX	D_F	= viscous force due to wetted surface, parallel to the planing surface, in lb
		$= (C_F + C_A)\ (\rho/2)\ (V_m^2)\ (b^2\ \lambda/\cos\beta)$
CK	C_K	$= 1.5708\ (1 - 0.1788\ \tan^2\beta\ \cos\beta - 0.09646\ \tan\beta\ \sin^2\beta)$
CK1	C_{K_1}	$= C_K\ \tan\tau/\sin\beta$
A1	a_1	$= \dfrac{[\sin^2\tau(1-2C_K)+C_K^2\tan^2\tau(1/\sin^2\beta-\sin^2\tau)]^{1/2}}{\cos\tau + C_K\ \tan\tau\ \sin\tau}$
TANρ	$\tan\phi$	$= \left(a_1+C_{K_1}\right)/\left(1-a_1\ C_{K_1}\right)$
THETA	θ	= angle between outer spray edge and keel in radians
		$= \arctan(\tan\phi\ \cos\beta)$
DLM	$\Delta\lambda$	= effective increase in length-beam ratio due to spray
		$= [\tan\beta/(\pi\ \tan\tau) - 1/(2\ \tan\theta)]/(2\ \cos\theta)$
RE	R_{n_s}	= Reynolds number for spray
		$= V\ b/(3\ \cos\beta\ \sin\theta)/\nu$
CF	C_{F_S}	= Schoenherr frictional resistance coefficient for spray drag
DSX	D_S	= viscous force due to spray drag, parallel to the planing surface, in lb
		$= C_{F_S}\ (\rho/2)\ (V^2)\ (b^2\ \Delta\lambda\ /\ \cos\beta)$
DWX	D_W	= component of wind drag parallel to planing surface in lb
		$= C_{D_W}'\ V^2/\cos\tau$
DTX	D_T	= total drag force parallel to planing surface in lb
		$= D_F + D_S + D_W$
PDBX	P_T	= total pressure force perpendicular to surface in lb
		$= \Delta/\cos\tau + D_T\ \tan\tau$

EDB	e_P	= moment arm from center of pressure to center of gravity in ft
		$= \overline{AG} - \overline{AP}$
FF	f_F	= moment arm from center of viscous force to center of gravity in ft
		$= \overline{KG} - (b \tan \beta / 4)$
FW	f_W	= moment arm from center of wind drag to center of gravity in ft
		$= \overline{KG} - H_W$
RMT	ΣM	= sum of moments about CG in ft-lb
		$= P_T \, e_P + (D_F + D_S) \, f_F + D_W \, f_W$
	Iterate with small changes in τ until $\Sigma M \leq 0.001 \Delta$	
NT	Number of iterations required to obtain equilibrium trim; maximum of 15 iterations	
R	R_h	= total horizontal resistance force in lb
		$= D_T \cos \tau + P_T \sin \tau$

NAME:	SUBROUTINE PRCOEF
PURPOSE:	Estimate propulsion coefficients for planing hull with propellers on inclined shafts
CALLING SEQUENCE:	CALL PRCOEF (FNV, TDF, ADF, TWF)
SUBPROGRAMS CALLED:	MINP, YINTE
INPUT:	
FNV	$F_{n\nabla}$ = speed-displacement coefficient = $V/(g\nabla^{1/3})^{1/2}$
OUTPUT:	
TDF	1-t = thrust deduction factor = total horizontal resistance of appendaged hull / total shaft-line thrust
ADF	η_a = appendage drag factor = resistance of bare hull / resistance of appendaged hull
TWF	1-w = thrust wake factor = torque wake factor
REFERENCE:	Blount, D.L. and D.L. Fox, "Small Craft Power Predictions," Western Gulf Section of the Society of Naval Architects and Marine Engineers (Feb 1975)
PROCEDURE:	1-t, 1-w, and η_a interpolated from following table of values at input value of $F_{n\nabla}$. The tabulated data represent mean values from a bandwidth of data collected for numerous twin-screw planing craft and reported in the above reference.

FV array	$F_{n\nabla}$ =	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
TDF	1-t =	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
TW array	1-w =	1.05	1.06	1.04	0.99	0.97	0.975	0.98	0.975
AD array	η_a =	0.951	0.948	0.942	0.934	0.925	0.913	0.900	0.885

NAME:	SUBROUTINE OWKTQ
PURPOSE:	Calculate propeller open-water characteristics as function of pitch ratio, expanded area ratio, and number of blades from coefficients derived from Wageningen B-Screw Series for airfoil section propellers or modified coefficients for flat face, segmental section propellers.
REFERENCE:	Oosterveld and Van Oossanan, "Recent Development in Marine Propeller Hydrodynamcis," Proceedings of the Netherlands Ship Model Basin 40th Anniversary (1972) and "Further Computer Analyzed Data of the Wageningen B-Screw Series," International Shipbuilding Progress, Vol. 22 (July 1975).
CALLING SEQUENCE:	CALL OWKTQ

INPUT:

IPROP	Control for type of propellers = 1 for Gawn-Burrill type (flat face, segmental sections) = 3 for Wageningen B-Screw type (airfoil sections)	
PD	P/D	= propeller pitch/diameter ratio (0.6 to 1.6)
EAR	EAR	= propeller expanded area ratio (0.5 to 1.1)
Z	Z	= number of propeller blades (3 to 7)

OUTPUT:

N	n_J	= number of J values generated -- max of 60
JT	J	= array of propeller advance coefficients in ascending order from (J=0) to (J at $K_T \approx 0$) in increments of 0.025 if P/D<1.2 in increments of 0.050 if P/D>1.2
KT	K_T	= array of open-water thrust coefficients = f (P/D, EAR, Z, J)
KQ	K_Q	= array of open-water torque coefficients = f (P/D, EAR, Z, J)

K_T and K_Q developed from equation in above references for airfoil section propellers. For Gawn-Burrill type propellers (IPROP=1) the equations are modified to produce slightly higher K_T and K_Q than B-Screw Series.

NAME: SUBROUTINE CAVKTQ

PURPOSE: Calculate propeller characteristics in cavitation regime as function of pitch ratio, expanded area ratio and cavitation number.

REFERENCE: Blount and Fox, "Design Considerations for Propellers in a Cavitating Environment," Marine Technology (Apr 1978)

CALLING SEQUENCE: CALL CAVKTQ

SUBPROGRAMS CALLED: TQMAX

INPUT:

IPROP	Control for type of propellers	= 1 for Gawn-Burrill type (flat face, segmental sections) = 2 for Newton-Rader types = 3 for Wageningen B-Screw (airfoil sections)
PD	P/D	= propeller pitch/diameter ratio
EAR	EAR	= propeller expanded area ratio
NJ	n_J	= number of J values input from open-water curves -- max. of 60
JT	J	= array of propeller advance coefficients
KTO	K_{T_O}	= corresponding array of propeller open-water thrust coefficients
KQO	K_{Q_O}	= corresponding array of propeller open-water torque coefficients
NS	n_s	= number of cavitation numbers -- max. of 8 -- at which propeller characteristics are to be computed and printed from this routine (if n_s = 0 only the constants are computed)
SIGMA	σ	= array of cavitation numbers

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GENERAL NOTATION FOR PROPELLERS:

V_A	=	propeller speed of advance
n	=	rate of revolution
D	=	propeller diameter
T	=	thrust
Q	=	torque
ρ	=	water density
p_o	=	pressure at center of propeller = $p_A + p_H - p_V$
J	=	advance coefficient = $V_A / (n\ D)$
K_T	=	thrust coefficient = $T / (\rho n^2 D^4)$
K_Q	=	torque coefficient = $Q / (\rho n^2 D^5)$
K_T/J^2	=	thrust loading = $T / (\rho D^2 V_A{}^2)$
K_Q/J^2	=	torque loading = $Q/(\rho D^3 V_A{}^2)$
K_Q/J^3	=	power loading = $Q\ n / (\rho D^2 V_A{}^3)$
σ	=	cavitation number based on advance velocity = $p_o / (1/2\ \rho V_A{}^2)$
$V_{0.7R}{}^2$	=	velocity ^{2} at 0.7 radius of propeller = $V_A{}^2 + (0.7 \pi nD)^2 = V_A{}^2 (J^2+4.84)/J^2$
$\sigma_{0.7R}$	=	cavitation number based on $V_{0.7R}$ = $P_o/(1/2\ \rho V_{0.7R}{}^2) = \sigma J^2/(J^2+4.84)$
A_P	=	projected area of propeller = $(\pi D^2/4)$ EAR $(1.067-0.229\ P/D)$
τ_c	=	thrust load coefficient = $T / (1/2\ \rho A_P V_{0.7R}{}^2)$ = $K_T / \left[1/2\ (A_P/D^2)\ (J^2+4.84)\right]$
Q_c	=	torque load coefficient = $Q / (1/2\ \rho D A_P V_{0.7R}{}^2)$ = $K_Q / \left[1/2\ (A_P/D^2)\ (J^2+4.84)\right]$

MAXIMUM THRUST AND TORQUE LOADS:

Blount and Fox (see reference) give equations for maximum thrust and torque load coefficients in a cavitating environment based on regression of experimental data for the three propeller series used herein.

τ_{c_m} = maximum thrust load coefficient
= $a\, \sigma_{0.7R}^{\,b}$ (transition region)
= τ_{c_x} (fully cavitating region)

Q_{c_m} = maximum torque load coefficient
= $c\, \sigma_{0.7R}^{\,d}$ (transition region)
= Q_{c_x} (fully cavitating region)

OUTPUT:

			IPROP
T1	a	= 1.2	1
	a	= 0.703 + 0.25 P/D	2
	a	= 1.27	3
T2	b	= 1.0	1
	b	= 0.65 + 0.1 P/D	2
	b	= 1.0	3
Q1	c	= 0.200 P/D	1
	c	= 0.240 P/D - 0.12	2
	c	= 0.247 P/D - 0.0167	3
Q2	d	= $0.70 + 0.31\ EAR^{0.9}$	1
	d	= 0.50 + 0.165 P/D	2
	d	= 1.04	3
TCX	τ_{c_x}	= 0.0725 P/D - 0.0340 EAR	1
	τ_{c_x}	= 0.0833 P/D - 0.0142 EAR	2
	τ_{c_x}	= 0.0	3
QCX	Q_{c_x}	= $[0.0185\ (P/D)^2 - 0.0166\ P/D + 0.00594]\ /EAR^{1/3}$	1
	Q_{c_x}	= $0.0335\ P/D - 0.024\ EAR^{1/2}$	2
	Q_{c_x}	= 0.0	3

RMAX k = 0.8

Since full-scale trial data (see Figures 5 and 6 of reference) indicates actual thrust and torque in the transition region less than the maximums derived from the propeller series data, the factor k is applied to τ_{c_m} and Q_{c_m} in the transition region. The factor k is not applied to τ_{c_x} and Q_{c_x}.

APD2	$A_p/D^2/2$	=	Constant for calculation of τ_c and Q_c
J	J	=	advance coefficient from input array
OPEN WATER KT KQ	$\left.\begin{matrix} K_{T_o} \\ K_{Q_o} \end{matrix}\right\}$	=	input values of open-water thrust and torque coefficients
SIGMA	σ	=	cavitation number from input array
KT	K_T	= =	thrust coefficient as f (J, σ) K_{T_o} or K_{T_m}, whichever is smaller
	K_{T_m}	=	τ_{c_m} (1/2 A_p/D^2) (J^2 +4.84)
	τ_{c_m}	=	(k a $\sigma_{0.7R}{}^b$) or (τ_{c_x}), whichever is greater
LC		=	1 character **identifier** for propeller cavitation C indicates more than 10% back cavitation for Gawn props: $\tau_c > 0.494\ \sigma_{0.7R}{}^{0.88}$ * indicates thrust limit due to cavitation $K_T = K_{T_m}$
KQ	K_Q	= =	torque coefficient as f (J, σ) K_{Q_o} or K_{Q_m}, whichever is smaller
	K_{Q_m}	=	Q_{c_m} (1/2 A_p/D^2) (J^2 + 4.84)
	Q_{c_m}	=	(k c $\sigma_{0.7R}{}^d$) or (Q_{c_x}), whichever is greater
			K_{T_m} and K_{Q_m} generated by Function TQMAX

NAME: FUNCTION TQMAX

PURPOSE: Calculate maximum thrust or torque coefficient in a cavitating environment as function of cavitation number and advance coefficient

CALLING SEQUENCE: X = TQMAX (SIGMA, JT, ITQ)

INPUT:

SIGMA	σ	=	cavitation number
JT	J	=	advance coefficient
ITQ	i	=	1 if maximum thrust coefficient required
	i	=	2 if maximum torque coefficient required

Variables: a, b, c, d, τ_{c_x}, Q_{c_x}, k, 1/2 A_p/D^2 generated by Subroutine CAVKTQ

OUTPUT:

TQMAX: K_{T_m} or K_{Q_m} depending on value of i

τ_{c_m} = maximum thrust load coefficient
= $k\ a\ \sigma_{0.7R}^{\ b}$, or τ_{c_x} if greater

$K_{T_m} = \tau_{c_m}\ (1/2\ Ap/D^2)\ (J^2+4.84)$

Q_{c_m} = maximum torque load coefficient
= $k\ c\ \sigma_{0.7R}^{\ d}$, or Q_{c_x} if greater

$K_{Q_m} = Q_{c_m}\ (1/2\ A_p/D^2)\ (J^2+4.84)$

NAME: SUBROUTINE PRINTP

PURPOSE: Interpolate for propeller performance at specified value of (1) advance coefficient J, (2) thrust loading K_T/J^2, (3) torque loading, K_Q/J^2, or (4) power loading K_Q/J^3.

CALLING SEQUENCE: CALL PRINTP (IP, PCOEF, SIGMA)

SUBPROGRAMS: TQMAX, YINTE

INPUT:

IP	Option	= 1, 2, 3, or 4		
PCOEF		=	input propeller coefficient, dependent on value of IP	
	J_T	=	advance coefficient,	input if IP=1
	K_T/J^2	=	thrust loading,	input if IP=2
	K_Q/J^2	=	torque loading,	input if IP=3
	K_Q/J^3	=	power loading,	input if IP=4
SIGMA	σ	=	cavitation number	
NJ	n_J	=	number of J values defining propeller characteristics	
JT	J	=	array of advance coefficient, in ascending order	
KT	K_{T_o}	=	array of open-water thurst coefficients	
KQ	K_{Q_o}	=	array of open-water torque coefficients	

PERFORMANCE AT SPECIFIC J:

JTP	J_T	=	input advance coefficient
KTP	K_T	=	thrust coefficient at J_T
		=	open-water thrust coefficient interpolated from input array of K_{T_o} versus J, or maximum thrust coefficient in cavitating regime K_{T_m} calculated by Function TQMAX, whichever is smaller.
KQP	K_Q	=	torque coefficient at J_T
		=	open-water value interpolated from K_{Q_o} vs J, or maximum cavitation value K_{Q_m} calculated from TQMAX, whichever is smaller

PERFORMANCE AT SPECIFIC LOADING:

PLOG	$\ln(K_T/J^2)$	if IP=2	natural log of input loading coefficient
	$\ln(K_Q/J^2)$	if IP=3	
	$\ln(K_Q/J^3)$	if IP=4	
XLOG	$\ln(K_{T_o}/J_o^2)$	if IP=2	array of natural logs of open-water loading coefficient at J value from input array
	$\ln(K_{Q_o}/J_o^2)$	if IP=3	
	$\ln(K_{Q_o}/J_o^3)$	if IP=4	

JTP $\quad J_{T_o}$ = open-water advance coefficient interpolated from array of open-water loading coefficients versus J at the specific loading required (logs are used because of the rapid change of loading coefficient at low J's)

If J_{T_o} is in non-cavitating region ($K_{T_o} < K_{T_m}$)

KTP	K_T	thrust and torque coefficients at J_{T_o}
KQP	K_Q	interplated from arrays of K_{T_o} and K_{Q_o} vs J

If J_{T_o} is in cavitating region ($K_{T_o} > K_{T_m}$)

XLOG	$\ln(K_{T_m}/J^2)$	if IP=2	array of natural logs of loading coefficients based on K_{T_m} or K_{Q_m} as function J
	$\ln(K_{Q_m}/J^2)$	if IP=3	
	$\ln(K_{Q_m}/J^3)$	if IP=4	

JTP $\quad J_{T_m}$ = advance coefficient interpolated from array of cavitation loading coefficients vs J at the specific loading required

KTP	KT	maximum cavitation thrust and torque
KQP	KQ	coefficients at J_{T_m} calculated from TQMAX

OUTPUT:

JTP	J_T	= final advance coefficient	at propeller performance point specified by PCOEF and SIGMA
KTP	K_T	= final thrust coefficient	
KQP	K_Q	= final torque coefficient	
EP	η_0	= propeller efficiency = $J_T K_T/(2\pi K_Q)$	

TAUC	τ_c	=	thrust load coefficient
		=	$K_T \,/\, \left[\frac{1}{2}(A_P/D^2)\ (J^2+4.84)\right]$
SIG7	$\sigma_{0.7R}$	=	cavitation number based on velocity at 0.7 radius of propeller
		=	$\sigma\ J^2/\ (J^2+4.84)$ $4.84=(0.7\pi)^2$
XSIG7	$4.94\ \sigma_{0.7R}^{0.88}$	=	term representing 10% back cavitation line for Gawn-Burrill propeller series
LT		=	1 character identifier for propeller cavitation

* indicates thrust limit due to cavitation:
$K_T = K_{T_m}$

C indicates more than 10% back cavitation for Gawn-Burrill propellers, but less than thrust limit cavitation

$$\tau_c > 0.494\ \sigma_{0.7R}^{0.88}$$

NAME	SUBROUTINE PROPS	
PURPOSE:	Estimate powering requirements for ship at design and cruise speeds with propellers on inclined shafts. Select appropriate number of propellers and/or propeller diameter, if not already specified	
CALLING SEQUENCE:	CALL PROPS	
SUBPROGRAMS CALLED:	YINTX, PRINTP	
INPUT:	Via COMMON blocks	
PROPNO	n_{pr}	= number of propellers--optional input on Card 12
PROPDI	D_{in}	= propeller diameter in inches--optional input on Card 12
AUXNO	n_{aux}	= number of auxiliary propulsion units for cruise speed operation, from input Card 12
PEMAX	$P_{e_{max}}$	= maximum horsepower of each prime mover, from input Card 12
PL	L_P	= ship length in ft, from input Card 29
HT	H_t	= draft at transom in ft, from Subroutine NEWHUL
NV	Number of speeds, from Subroutine POWER	
VKT(I)	V_K	= ship speed in knots, from Subroutine POWER
		= design speed V_d, cruise speed V_c when I = 1, 2
TWF(I)	1-w	= thrust wake factor, from Subroutine PRCOEF
THRUST(I)	T	= total shaft-line thrust in lb, from Subroutine POWER
EHP(I)	P_E	= total effective power, from Subroutine POWER
APD2	$\frac{1}{2}A_p/D^2$	= propeller constant, from Subroutine CAVKTQ
TCDES	$(\tau_c/\sigma_{0.7R})^*$	= constant for sizing propeller, from Card 12 ≈ 0.6 for Gawn-Burrill 10% back cavitation criteria
CONSTANTS:		
PRA	p_A	= atmospheric pressure in lb/ft^2 = 2116
PRV	p_V	= vapor pressure in lb/ft^2 = 36

PRH	p_H	= static water pressure at propeller center in lb/ft^2
		$= \rho\ g\ h_{pr}$
	h_{pr}	= depth of propeller center below waterline in ft
		$= H_t + 0.75\ D \approx 1.5\ H_t$, if D not defined
EEMAX	ε_{max}	= maximum shaft angle in degrees = 15
OPC		Preliminary estimate of $\eta_D = 0.55$

OUTPUT:

PRSHP	P_{B_o}	= preliminary estimate of total brake horsepower
		$= 0.55\ P_E$ at design speed
NPR	n_{pr}	= number of prime movers = number of propellers
		$= P_{B_o} / P_{e_{max}}$ (rounded up)
		or value specified on input Card 12
		Limits: $4 \leq n_{pr} \leq 2$
I		Index for DO LOOP I=1, NV
VA(I)	V_A	= speed of advance of propeller in ft/sec
		$= 1.6878\ V_K\ (1-w)$
SIG(I)	σ	= cavitation number $= (p_A+p_H-p_V)/(\frac{1}{2}\rho\ V_A^2)$
TLMAX	$(K_T/J^2)^*$	= upper limit on thrust loading
		$= \frac{1}{2}(A_p/D^2)\ \ \sigma\ (\tau_c/\sigma_{0.7R})^*$
DM	D_{min}	= diameter in inches of smallest propeller capable of producing required thrust at current speed
		$= 12 \left[T / \rho\ V_A^2\ n_{po}\ (K_T/J^2)^* \right]^{1/2}$

	n_{po}	= number of propellers in operation = n_{pr} at design speed = n_{pr} at cruise speed, if no auxiliary engine = n_{aux} at cruise speed, if $n_{aux} > 0$
DIN	D_{in}	= final propeller diameter in inches = 1.05 D_{min} at design speed or 1.05 D_{min} at cruise speed, whichever if larger or value specified on input Card 12
XSH	X_{sh}	= longitudinal distance from transom to point where shafting enters hull in ft = 0.2 L_p
XSF	X_{sf}	= longitudinal distance from transom to forward end of shafting in ft = 0.3 L_p
CRUD	C_r	= chord length of rudder in ft = $0.03464\ L_p/n_{pr}^{1/2}$ Trailing edge of rudder assumed flush with transom Projected area of each rudder = $0.0016\ L_p^2/n_{pr}$ = $4/3\ C_r^2$
DMAX	D_{max}	= maximum propeller diameter in inches, limited by ε_{max} and 0.25 D tip clearance = $12\ (X_{sh}-C_r)\tan\varepsilon_{max}/0.75\ (1+\tan\varepsilon_{max})$ If $D_{in} > D_{max}$, n_{pr} is increased and D_{in} is recalculated, unless n_{pr} is a fixed input value or up to the limit of 4
PRN	n_{pr}	= final number of propellers, prime movers
DINMAX	$D_{max'}$	= maximum propeller diameter in inches, limited by hull breadth over chines at transom = $12\ (2\ Y_{C_1})\ /\ [n_{pr} + 0.25\ (n_{pr} - 1)]$ If $D_{in} > D_{max'}$, set final $D_{in} = D_{max'}$
DFT	D	= final propeller diameter in ft = $D_{in}/12$
XSA	X_{sa}	= longitudinal distance from transom to aft end of shafting at propeller centerline = 0.75 D + C_r, assuming 0.25 D from rudder to propeller
D75	H_{sa}	= height from aft end of shafting to hull in ft = 0.75 D, assuming 0.25 D propeller tip clearance

EE	ϵ	= shaft angle in degrees
		$= \arctan[H_{sa}/(X_{sf}-X_{sa})]$
SHL	L_{sh}	= shaft length in ft = $(X_{sf}-X_{sa})/\cos\epsilon$
THLD(I)	K_T/J^2	$= T/[n_{po}\ \rho\ V^2\ (1-w)^2\ D^2]$
		= thrust loading of final propellers
TJ	J	= advance coefficient, from Subroutine PRCHAR
EP(I)	η_O	= propeller efficiency, from Subroutine PRCHAR
RCF	N_{corr}	= rpm correction factor, from Subroutine PRCHAR
RPM(I)	N	= propeller rpm = $60\ V\ (1-w)\ N_{corr}/(J\ D)$
PC(I)	η_D	= propulsive coefficient = $\eta_O\ \eta_H\ \eta_R$
	η_H	= hull efficiency = $(1-t)/(1-w)$
	η_R	= relative rotative efficiency = 1.0 since thrust wake and torque wake are assumed equal
DHP(I)	P_D	= total horsepower developed at propellers
		$= P_E\ /\ \eta_D$
SHP(I)	P_S	= total shaft horsepower = 1.02 P_D assuming 2 percent shaft transmission losses

NAME:	SUBROUTINE WJETS	
PURPOSE:	Design waterjet pumps capable of producing reauired thrust at design and cruise speeds and estimated powering requirements. Select appropriate number of waterjets if not already specified.	
REFERENCE:	Denny, S.B. and A.R. Feller, "Waterjet Propulsor Performance Prediction in Planing Craft Applications," DTNSRDC Report SPD-0905-01 (Aug 1979)	
CALLING SEQUENCE:	CALL WJETS	
SUBPROGRAMS CALLED:	YINTE	
INPUT:	Via COMMON blocks	
PROPNO	n_{pr}	= number of prime movers = number of waterjet pumps -- optional input on Card 12
AUXNO	n_{aux}	= number of auxiliary propulsion units for cruise speed operation, from input Card 12
PEMAX	$P_{e_{max}}$	= maximum horsepower of each prime mover, from Card 12; required if n_{pr} not specified
PROPDI	D_{in}	= impeller diameter in inches -- optional input on Card 12
AJET	A_j	= area of jet in ft^2 -- optional input on Card 12A
XK1	K_1	= bollard jet velocity/ship speed at design point, input from Card 12A
XK2	K_2	= constant for inlet head recovery IHR, from Card 12A
XK3	K_3	= constant for τ_c vs. σ_{TIP} cavitation criteria, from Card 12A
DHD	D_h/D	= diameter of impeller hub/diameter of impeller, input from Card 12A
TLC	τ_{c_d}	= thrust load coefficient at design point, from Card 12A; not used if A_J is input
STP	σ_{TIP_d}	= impeller tip velocity cavitation number at design point, from Card 12A
HT	H_t	= draft at transom in ft, from Subroutine NEWHUL
NV	Number of speeds, from Subroutine POWER	
VKI(I)	V_K	= ship speed in knots, from Subroutine POWER = design speed V_d, cruise speed V_c, when I=1,2

THRUST(I)	T	= total thrust required in lb, from Subroutine POWER

CONSTANTS:

PRA	P_A	= atmospheric pressure in lb/ft^2 = 2116
PRV	P_V	= vapor pressure in lb/ft^2 = 36
PRH	P_H	= static water pressure on rotating axis in $lb/ft^2 = \rho g h_{ra}$
	h_{ra}	= depth of rotating axis below waterline in ft ≥ 0
OPC	Preliminary estimate of η_D = 0.4	
RHO	ρ	= water density in lbs x sec^2/ft^4= 1.9905
GA	g	= acceleration of gravity in ft/sec^2 = 32.174

OUTPUT:

PRSHP	P_{B_o}	= preliminary estimate of total brake power = 0.4 P_E at design speed
NPR	n_{pr}	= number of prime movers = number of waterjets = $P_{B_o}/P_{e_{max}}$ (rounded up) or value specified on Card 12 Limits: $4 \leq n_{pr} \leq 2$
VFPS(1)	V_{S_d}	= design ship speed in ft/sec = 1.6878 V_{K_1}
VFPS(2)	V_{S_c}	= cruise ship speed in ft/sec = 1.6878 V_{K_2}
THI(1)	T_d	= thrust requirement in lb for each waterjet at design speed = T_1/n_{pr}
THI(2)	T_c	= thrust in lb for each waterjet at cruise speed = T_2/n_{aux} or T_2/n_{pr} when n_{aux} = 0
VJB	V_{JB_d}	= bollard jet velocity in ft/sec at full power = $K_1 V_{S_d}$
DVJ	ΔV_{J_d}	= increase in jet velocity due to IHR at V_{S_d} = $K_2 V_{S_d} [(V_{JB_d}/V_{S_d}) + 1]^{-1.737}$
VJ	V_{J_d}	= jet velocity in ft/sec at V_{S_d} = $V_{JB_d} + \Delta V_{J_d}$
Q	Q_d	= mass flow in ft^3/sec at V_{S_d} = $A_J V_{J_d}$, if A_J is input = $T_d/[\rho (V_J - V_S)]$, if A_J is not specified

AJ	A_J	= area of jet in ft = Q_d/V_{J_d} or value from Card 12A
AI	A_I	= open area of pump inlet in ft^2 = $(\pi D^2/4)(1 - D_h{}^2/D^2)$, if D is input = $T_d\ \sigma_{TIP_d}\ /\tau_{c_d}/(p_A+p_H-p_V)$, if D not specified
VID	V_I	= average flow velocity into pump inlet at design point in ft/sec = Q_d/A_I
DMAX	D_{max}	= maximum impeller diameter in ft, so that the center of rotating axis will not be above the still waterline = $H_t{}'/1.25$, where $H_t{}'$ is draft at 1/4 buttock at transom
DFT	D	= diameter of pump impeller in ft = $D_{in}/12$, if D_{in} is input = $[4A_I/\pi(1-D_h{}^2/D^2)]^{1/2}$, if D_{in} not specified If D calculated>D_{max}, set $D=D_{max}$
DIN	D_{in}	= diameter of pump impeller in inches = 12 D, or value input on Card 12
DHPMAX	P_{max}	= maximum input horsepower = $(\rho A_J\ V_{JB_d}{}^3/620.517)^{0.94733}$
RPMMAX	N_{max}	= pump speed in rpm at full power = $60\ [p_A+p_H-p_V)/(1/2\ \rho\sigma_{TIP_d}) - V_{I_d}{}^2]^{1/2}/(\pi D)$
I		Index for DO LOOP I=1,NV (NV = number of speeds = 2)
VS	V_{S_i}	= ship speed in ft/sec (design speed, cruise speed, i = 1,2)
J		Index for DO LOOP J=1,NHP (NHP = 4) Calculate thrust at 4 selected values of horsepower Interpolate to obtain horsepower required at specified speed
HP(J)	P_j	= selected horsepower = (J/4) P_d
VJB	V_{JB_j}	= bollard jet velocity in ft/sec at P_j = $[620.517\ P_j{}^{1.0556}/\ (\rho A_J)]^{1/3}$

DVJ	ΔV_{J_j}	= increase in jet velocity at P_j and V_{S_i}
		$= K_2 V_{S_i} [(V_{JB_j}/V_{S_i}) + 1]^{-1.737}$
VJ	V_{J_j}	= jet velocity at P_j and $V_{S_i} = V_{JB_j} + \Delta V_{J_j}$
Q	Q_j	= mass flow at P_j and $V_{S_i} = A_J V_{J_j}$
TH(J)	T_j	= thrust in lb at P_j and V_{S_i}
		$= \rho Q_j (V_{J_j} - V_{S_i})$
DHP(I)	P_i	= input horsepower for required thrust at specified ship speed. interpolated from array of P_j vs T_j ac input value of T_i
RPM(I)	N_i	= pump speed in rpm
		$= N_{max} (P_i/P_{max})^{1/3}$
VJB	V_{JB_i}	= bollard jet velocity at required input horsepower in ft/sec
		$= [620.517 P_i^{1.0556}/(\rho A_J)]^{1/3}$
DVJ	ΔV_{J_i}	= increase in jet velocity due to IHR
		$= K_2 V_{S_i} [(V_{JB_i}/V_{S_i}) + 1]^{-1.737}$
VJ	V_{J_i}	= jet velocity in ft/sec $= V_{JB_i} + \Delta V_{J_i}$
Q	Q_i	= mass flow in ft^3/sec $= A_J V_{J_i}$
V1	V_{I_i}	= average flow velocity into pump inlet in ft/sec $= Q_i/A_I$
SIG(I)	σ_i	= cavitation number $= (p_A + p_H - p_V)/(1/2 \rho V_I^2)$
RPS	n_i	= pump speed in rps $= N_i/60$
SIGTIP	σ_{TIP_i}	= impeller tip velocity cavitation number
		$= (P_A + P_H - P_V)/[1/2 \rho (V_{I_i}^2 + \pi^2 n_i^2 D^2)]$
TAUC	τ_{c_i}	= thrust load coefficient
		$= T_i/[1/2 \rho A_I (V_{I_i}^2 + \pi^2 n_i^2 D^2)]$
TCMAX	τ_{max_i}	= cavitation limit on thrust load coefficient
		$= \sigma_{TIP_i} + 0.14 K_3$
TCD(I)	$(\tau_{max_i} - \tau_{c_i})$	negative value indicates cavitation
QG(I)	Q'_i	= mass flow in gal/min = 448.828 Q_i

XNPSH(I)	$NPSH_i$	= net positive suction head
		$= (V_I{}^2/2g)(1 + \sigma)$
SS(I)	S_{S_i}	= suction specific speed
		$= N_i(Q'_i)^{1/2}/(NPSH)^{3/4}$
XJ(I)	J'_i	= effective advance coefficient = V_{I_i}/n_iD
PRNN	n_{po_i}	= number of pumps in operation
		$= n_{pr}$ at design speed (i = 1)
		$= n_{aux}$ at cruise speed if $n_{aux} > 0$ (i=2)
		$= n_{pr}$ at cruise speed if $n_{aux} = 0$ (i=2)
DHP(I)	P_{D_i}	= total horsepower developed at pumps
		$= P_i\ n_{po_i}$
SHP(I)	P_{S_i}	= total shaft horsepower = P_{D_i}

NAME:	SUBROUTINE DISCOT
PURPOSE:	Single or double interpolation for continuous or discontinuous function using Lagrange's formula
CALLING SEQUENCE:	CALL DISCOT (XA, ZA, TABX, TABY, TABZ, NC, NY, NZ, ANS)
SUBPROGRAMS CALLED:	UNS, DISSER, LAGRAN These subroutines are concerned with the interpolation, and are not documented separately
INPUT:	
XA	x value (first independent variable) for interpolated point
ZA	z value (second independent variable) for interpolated point Same as x value for single-line function interpolation
TABX array	Table of x values--first independent variable
TABY array	Table of y values--dependent variable
TABZ array	Table of z values--second independent variable
NC	Three digit control integer with ± sign Use + sign if NX = NY/NZ = points in X array Use - sign if NX = NY Use 1 in hundreds position for no extrapolation above maximum Z Use 0 in hundreds position for extrapolation above maximum Z Use 1-7 in tens position for degree of interpolation desired in X direction Use 1-7 in units position for degree of interpolation desired in Z direction
NY	Number of points in y array
NZ	Number of points in z array
OUTPUT:	
ANS	y value (dependent variable) interpolated at x, z DISCOT is a "standard" routine used at DTNSRDC. Consult User Services Branch of the Computation, Mathematics and Logistics Department for additional information.

NAME: FUNCTION MINP

PURPOSE: Select index of minimum x value to be used for Lagrange interpolation, from an array of x values greater than required

CALLING SEQUENCE: I = MINP (M, N, XA, X)

INPUT:

M	m = number of points required for interpolation of degree m-1
N	n = total number of points in x array $\geq$ m
XA	x value to be used for interpolation
X array	Table of x values, must be in ascending order, but need not be equally spaced

OUTPUT:

MINP	Index of minimum x value from the array to be used by FUNCTION YINTE for Lagrange interpolation of degree m-1

SAMPLE PROGRAM USING FUNCTIONS MINP AND YINTE:

```
DIMENSION X(10), Y(10)
N  = 10
M  = 4
READ (5, 10) (X(J), J=1, N), (Y(J), J=1, N), XA
I  = MINP (M, N, XA, X)
YA = YINTE (XA, X(I), Y(I), M)
```

ALTERNATE PROGRAM USING FUNCTION YINTX:

```
DIMENSION X(10), Y(10)
N  = 10
M  = 4
READ (5, 10) (X(J), J=1, N), (Y(J), J=1, N), XA
YA = YINTX (XA, X, Y, M, N)
```

The result from either program is the same. In either case, only the M points closest to XA are considered in the interpolation formula. The first combination should be used whenever several dependent variables are to be interpolated at some value of the independent variable, since MINP need only be called once. FUNCTION YINTE may be used alone whenever N = M.

NAME:	FUNCTION YINTE
PURPOSE:	Single interpolation of degree n-1 for function represented by n (x,y) points using Lagrange's formula
CALLING SEQUENCE:	YA = YINTE (XA, X, Y, N)
INPUT:	
XA	x value (independent variable) for interpolated point
X array	Table of x values--independent variable x values can be in either ascending or descending order and do not need to be equally spaced
Y array	Table of y values--dependent variable
N	n = number of (x,y) values defining the function
OUTPUT:	
YINTE	Interpolated y value (dependent variable) derived from Lagrange formula of degree n-1 For example, when n = 4, cubic interpolation is performed

Lagrange's Interpolation Formula

$$y = \frac{(x-x_1)\ (x-x_2)\ .\ .\ .\ (x-x_n)}{(x_0-x_1)\ (x_0-x_2)\ .\ .\ .\ (x_0-x_n)}\ y_0$$

$$+ \frac{(x-x_0)\ (x-x_2)\ .\ .\ .\ (x-x_n)}{(x_1-x_0)\ (x_1-x_2)\ .\ .\ .\ (x_1-x_n)}\ y_1$$

$$+ \frac{(x-x_0)\ (x-x_1)\ (x-x_3)\ .\ .\ .\ (x-x_n)}{(x_2-x_0)\ (x_2-x_1)\ (x_2-x_3)\ .\ .\ .\ (x_2-x_n)}\ y_2 + .\ .\ .$$

$$+ \frac{(x-x_0)\ (x-x_1)\ (x-x_2)\ .\ .\ .\ (x-x_{n-1})}{(x_n-x_0)\ (x_n-x_1)\ (x_n-x_2)\ .\ .\ .\ (x_n-x_{n-1})}\ y_n$$

NAME:	FUNCTION YINTX
PURPOSE:	Single interpolation of degree m-1 for function represented by n (x,y) points using Lagrange's formula. If n > m, only the m closest points are considered in the interpolation formula
CALLING SEQUENCE:	YA = YINTX (XA, X, Y, M, N)
INPUT:	
XA	x value (independent variable) for interpolated point
X array	Table of x values--independent variable x values must be in ascending order, but need not be equally spaced
Y array	Table of y values--dependent variable
M	m = number of (x,y) values considered for the interpolation process of degree m-1
N	n = total number of (x,y) values $\geq$ m
OUTPUT:	
YINTX	Interpolated y value (dependent variable) derived from Lagrange formula of degree m-1
	FUNCTION YINTX may be used instead of FUNCTION MINP and FUNCTION YINTE together
	See Sample Programs using these three functions

NAME:	FUNCTION SIMPUN
PURPOSE:	Numerical integration of area under curve defined by set of (x,y) points at either equal or unequal intervals
CALLING SEQUENCE:	AREA = SIMPUN (X, Y, N)
INPUT:	
X array	Table of x values--independent variable x values must be in ascending order
Y array	Table of y values--dependent variable
N	Number of (x,y) values
OUTPUT:	
SIMPUN	Area under curve $\approx \int y \, dx$

NAME:	FUNCTION C1DSF
PURPOSE:	Calculate Schoenherr frictional resistance coefficient
CALLING SEQUENCE:	CF = C1DSF (XN1RE)
INPUT:	
XN1RE	R_n = Reynolds number = $V \ L \ / \ \nu$
OUTPUT:	
C1DSF	C_F = Schoenherr frictional resistance coefficient
PROCEDURE:	Iteration with Newton-Raphson method Schoenherr formula: $0.242 \ / \sqrt{C_F} = \log_{10} R_n \ C_F$

LIBRARY SUBPROGRAMS:

			Example
ABS	$\lvert a \rvert$	= absolute value of a	B = ABS (A)
AMIN1	Min(a, b, ...)	= smallest value in list	C = AMIN1 (A,B)
ALOG	$\log_e(a)$	= natural logarithm of a	D = ALOG (A)
ALOG10	$\log_{10}(a)$	= common logarithm of a	E = ALOG10 (A)
ATAN	arctan(a)	= arctangent of a	F = ATAN (A)
	arctan(a/b)	= arctangent of a/b	G = ATAN (A,B)
COS	cos(a)	= trigonometric cosine of a	P = COS (A)
EXP	e^a	= exponential of a	Q = EXP (A)
SIN	sin(a)	= trigonometric sine of a	R = SIN (A)
SQRT	$(a)^{1/2}$	= square root of a	S = SQRT (A)
TAN	tan(a)	= trigonometric tangent of a	T = TAN (A)

Note: Angle A must be in radians for trigonometric functions SIN, COS, TAN

APPENDIX B

SAMPLE INPUT AND OUTPUT

SAMPLE INPUT FOR PROGRAM PHFMOPT

```
LIST INPHFM.DA
  SAMPLE       ( DEC 80 )
 229.66    36.34     1.67
 27  26   13  15   18
  9   1    4   6    9  12   15   18   21   26
   .000     1817     1890      143      470     1765
   .025     1817     1900      136      479     1792
   .050     1817     1920      129      488     1820
   .075     1817     1937      122      497     1841
   .100     1817     1955      115      505     1864
   .150     1817     1988      100      522     1913
   .200     1817     2025       85      540     1965
   .250     1813     2060       70      558     2020
   .300     1808     2090       55      575     2070
   .350     1800     2125       40      592     2112
   .400     1785     2160       25      610     2165
   .450     1765     2200       10      628     2210
   .500     1730     2235       00      645     2250
   .550     1672     2260       00      662     2288
   .600     1585     2292       00      680     2322
   .650     1475     2295       00      698     2360
   .700     1345     2278       00      715     2390
   .750     1190     2220       08      732     2412
   .800     1015     2120       20      750     2438
   .850      805     1950       42      772     2450
   .875      690     1842       80      783     2455
   .900      555     1710      130      795     2458
   .925      435     1570      232      810     2460
   .950      300     1395      380      822     2460
   .975      260     1190      565      838     2455
  1.000       00      950      850      850     2450
  1.080       00       00     2404       00     2404
  1   0    1   1    1   0    0
   45.0      0.0     5.66     30.0    1000.     7.36     1.0      0.0
    10.      15.      20.      25.      30.      33.      36.      39.      42.      45.
   15.5     250.      4.0      4.0      1.0
    16.      10.       3.       3.      12.
   4.0.0666667       166.   18000.    5000.     150.
     3.       0.     60.0    4080.    1900.      1.4      1.0      3.0      0.6
    1.0      1.0      1.0      1.0      1.0      1.0
 16000.     200.      0.9
 14771.    3500.      0.0      0.0    7500.
    1.0      1.0      1.0      1.0      1.0      1.0
   1.10      1.0      1.0      1.0      1.0      1.0      1.0      1.0      1.0      1.0
    1.0      1.0      1.0
   1.10      1.0      1.0      1.0      1.0      1.0      1.0      1.0      1.0
   1.10      1.0      1.0      1.0      1.0
   1.10      1.0      1.0
   1.10      1.0      1.0      0.0      1.0      1.0      1.0      1.0      1.0      1.0
    1.0      0.0      0.0      1.0      1.0      1.0      0.0      1.0      1.0      1.0
   1.10      1.0      1.0      1.0      1.0      1.0      1.0      1.0      0.5
    0.0      0.0      1.0      0.7      1.0      0.0
  2.191    1.000    2.036    1.000    1.528    1.000    1.000
   100.     15.0     10.0      0.1      0.9     250.
    5.0      0.5      0.5      0.0     30.0     10.0     20.0
 101.85   177.36    20.47    14.00
```

LIST OTPHFM.DA

ECHO OF INPUT DATA FROM SUBROUTINE READIN

ECHO OF INPUT DATA

SAMPLE (DEC 80)

229.66 36.34 1.67

27 26 13 15 18

9 1 4 6 9 12 15 18 21 26

0.000	18.17	18.90	1.43	4.70	17.65	0.00
0.025	18.17	19.00	1.36	4.79	17.92	0.00
0.050	18.17	19.20	1.29	4.88	18.20	0.00
0.075	18.17	19.37	1.22	4.97	18.41	0.00
0.100	18.17	19.55	1.15	5.05	18.64	0.00
0.150	18.17	19.88	1.00	5.22	19.13	0.00
0.200	18.17	20.25	0.85	5.40	19.65	0.00
0.250	18.13	20.60	0.70	5.58	20.20	0.00
0.300	18.08	20.90	0.55	5.75	20.70	0.00
0.350	18.00	21.25	0.40	5.92	21.12	0.00
0.400	17.85	21.60	0.25	6.10	21.65	0.00
0.450	17.65	22.00	0.10	6.28	22.10	0.00
0.500	17.30	22.35	0.00	6.45	22.50	0.00
0.550	16.72	22.60	0.00	6.62	22.88	0.00
0.600	15.85	22.92	0.00	6.80	23.22	0.00
0.650	14.75	22.95	0.00	6.98	23.60	0.00
0.700	13.45	22.78	0.00	7.15	23.90	0.00
0.750	11.90	22.20	0.08	7.32	24.12	0.00
0.800	10.15	21.20	0.20	7.50	24.38	0.00
0.850	8.05	19.50	0.42	7.72	24.50	0.00
0.875	6.90	18.42	0.80	7.83	24.55	0.00
0.900	5.55	17.10	1.30	7.95	24.58	0.00
0.925	4.35	15.70	2.32	8.10	24.60	0.00
0.950	3.00	13.95	3.80	8.22	24.60	0.00
0.975	2.60	11.90	5.65	8.38	24.55	0.00
1.000	0.00	9.50	8.50	8.50	24.50	0.00
1.080	0.00	0.00	24.04	0.00	24.04	0.00

1 0 1 1 1 0 0 0

45.00	0.00	5.66	30.00	1000.00	7.36	1.00	0.00	0.00	0.00
10.00	15.00	20.00	25.00	30.00	33.00	36.00	39.00	42.00	45.00
15.50	250.00	4.00	4.00	1.00					
16.00	10.00	3.00	3.00	12.00					
4.00	0.07	166.00	18000.02	5000.00	150.00				
3.00	0.00	60.00	4080.00	1900.00	1.40	1.00	3.00	0.60	
1.00	1.00	1.00	1.00	1.00	1.00				
16000.02	200.00	0.90							
14771.02	3500.00	0.00	0.00	7500.00	0.00	0.00	0.00	0.00	0.00
1.00	1.00	1.00	1.00	1.00	1.00				
1.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00							
1.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
1.10	1.00	1.00	1.00	1.00					
1.10	1.00	1.00							
1.10	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	0.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00
1.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.00
0.00	0.00	1.00	0.70	1.00	0.00				
2.19	1.00	2.04	1.00	1.53	1.00	1.00			
100.00	15.00	10.00	0.10	0.90	250.00				
5.00	0.50	0.50	0.00	30.00	10.00	20.00			

HULL STRUCTURES ALUM. SAMPLE (DEC 80)

		DESIGN P (PSI)	UNIT WT. (LB/SQ.FT)	AREA (SQ.FT)	WEIGHT (LB)	T (IN)
LOWER PLATFORM DECK		5.33	4.36	1524.3	6639.	
TRANSVERSE BULKHEADS						
1	X=0.000	6.39	4.64	197.8	918.	
2	X=0.075	6.64	4.44	209.3	930.	
3	X=0.150	6.88	4.46	220.8	985.	
4	X=0.300	7.40	4.49	245.4	1103.	
5	X=0.450	7.37	4.52	266.6	1206.	
6	X=0.600	8.19	4.55	271.1	1232.	
7	X=0.750	8.40	4.56	243.5	1110.	
8	X=0.875	8.33	4.56	178.5	813.	
9	X=1.000	6.39	4.43	63.3	280.	
5	X=0.450	11.99	0.00	266.6	1419.	
6	X=0.600	12.64	0.00	271.1	1461.	
6	X=0.600	4.56	0.00	83.3	1486.	
7	X=0.750	5.36	0.00	69.9	1135.	
LONGITUDINAL BULKHEADS						
1		5.33	4.36	536.5	2146.	
FRAMING (LONG.+TRANSVERSE)					16353.	

STRESS(PSI) = 4739.
T(IN) = 0.41 0.34 0.30

	DESIGN P (PSI)	UNIT WT. (LB/SQ.FT)	AREA (SQ.FT)	WEIGHT (LB)	T (IN)
HULL BOTTOM (BELOW CHINE)	25.09	5.67	1278.0	11143.	0.41
	50.19	7.35	530.0		
HULL SIDES (ABOVE CHINE)		4.64	2340.6	10862.	0.34
MAIN DECK	1.78	4.12	2413.1	9938.	0.30

STRUCTURAL DATA FROM SUBROUTINE STRUCT (PRINTED ONLY IF IOPT = 0)

PROPELLER CHARACTERISTICS IPROP = 1 P/D = 1.400 EAR = 1.000 3. BLADES

OPEN-WATER

J KT KQ EP KT/J2 KQ/J2 KQ/J3 TC QC S.7/S

T1	T2	Q1	Q2	TCX	QCX	RMAX	APD2
1.2000	1.0000	0.2800	1.0100	0.0675	0.0190	0.8000	0.2931

	OPEN-WATER CHARACTERISTICS				SIGMA= 6.00	SIGMA= 3.50	SIGMA= 2.00	SIGMA= 1.50	SIGMA= 1.00	SIGMA= 0.75	SIGMA= 0.50
J	KT	KQ	EP	KT/JSQ	KT KQ	KT KQ	KT KQ	KT KQ	KT KQ	KT KQ	KT KQ
0.000	0.817	0.1719	0.000	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.005	0.815	0.1716	0.004	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.010	0.813	0.1712	0.008	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.015	0.811	0.1709	0.011	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.020	0.809	0.1705	0.015	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.025	0.806	0.1701	0.019	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.035	0.802	0.1694	0.026	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.050	0.796	0.1683	0.038	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.075	0.785	0.1663	0.056	0.000	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.100	0.773	0.1643	0.075	77.308	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269	0.096*0.0269
0.150	0.749	0.1600	0.112	33.301	0.096*0.0270	0.096*0.0270	0.096*0.0270	0.096*0.0270	0.096*0.0270	0.096*0.0270	0.096*0.0270
0.200	0.724	0.1554	0.148	18.108	0.096*0.0271	0.096*0.0271	0.096*0.0271	0.096*0.0271	0.096*0.0271	0.096*0.0271	0.096*0.0271
0.250	0.698	0.1505	0.185	11.174	0.106*0.0272	0.097*0.0272	0.097*0.0272	0.097*0.0272	0.097*0.0272	0.097*0.0272	0.097*0.0272
0.300	0.671	0.1455	0.220	7.460	0.152*0.0347	0.097*0.0274	0.097*0.0274	0.097*0.0274	0.097*0.0274	0.097*0.0274	0.097*0.0274
0.350	0.644	0.1402	0.256	5.254	0.207*0.0473	0.121*0.0276	0.098*0.0276	0.098*0.0276	0.098*0.0276	0.098*0.0276	0.098*0.0276
0.400	0.615	0.1347	0.291	3.845	0.270*0.0620	0.158*0.0360	0.099*0.0278	0.099*0.0278	0.099*0.0278	0.099*0.0278	0.099*0.0278
0.450	0.586	0.1290	0.325	2.894	0.342*0.0786	0.199*0.0456	0.114*0.0280	0.100*0.0280	0.100*0.0280	0.100*0.0280	0.100*0.0280
0.500	0.556	0.1232	0.359	2.225	0.422*0.0973	0.246*0.0564	0.141*0.0321	0.106*0.0283	0.101*0.0283	0.101*0.0283	0.101*0.0283
0.550	0.526	0.1173	0.393	1.739	0.511*0.1173	0.298*0.0684	0.170*0.0389	0.128*0.0291	0.102*0.0286	0.102*0.0286	0.102*0.0286
0.600	0.495	0.1113	0.425	1.376	0.495C0.1113	0.355*0.0816	0.203*0.0463	0.152*0.0347	0.103*0.0289	0.103*0.0289	0.103*0.0289
0.650	0.465	0.1051	0.457	1.100	0.465C0.1051	0.416*0.0959	0.238*0.0545	0.178*0.0407	0.119*0.0292	0.104*0.0292	0.104*0.0292
0.700	0.434	0.0990	0.488	0.885	0.434 0.0990	0.434C0.0990	0.276*0.0633	0.207*0.0473	0.138*0.0314	0.105*0.0296	0.105*0.0296
0.750	0.402	0.0927	0.518	0.715	0.402 0.0927	0.402C0.0927	0.317*0.0727	0.237*0.0544	0.158*0.0361	0.119*0.0300	0.107*0.0300
0.800	0.371	0.0865	0.546	0.580	0.371 0.0865	0.371C0.0865	0.360*0.0828	0.270*0.0619	0.180*0.0411	0.135*0.0308	0.108*0.0304
0.850	0.340	0.0803	0.573	0.471	0.340 0.0803	0.340 0.0803	0.340C0.0803	0.305*0.0700	0.203*0.0465	0.152*0.0348	0.110*0.0309
0.900	0.310	0.0741	0.598	0.382	0.310 0.0741	0.310 0.0741	0.310C0.0741	0.310C0.0741	0.228*0.0522	0.171*0.0390	0.114*0.0314
0.950	0.279	0.0679	0.621	0.309	0.279 0.0679	0.279 0.0679	0.279 0.0679	0.279C0.0679	0.254*0.0582	0.190*0.0435	0.127*0.0319
1.000	0.249	0.0619	0.640	0.249	0.249 0.0619	0.249 0.0619	0.249 0.0619	0.249 0.0619	0.249C0.0619	0.211*0.0482	0.141*0.0324
1.050	0.219	0.0559	0.656	0.199	0.219 0.0559	0.219 0.0559	0.219 0.0559	0.219 0.0559	0.219C0.0559	0.219C0.0532	0.155*0.0353
1.100	0.190	0.0500	0.666	0.157	0.190 0.0500	0.190 0.0500	0.190 0.0500	0.190 0.0500	0.190 0.0500	0.190C0.0500	0.170*0.0388
1.150	0.162	0.0443	0.669	0.123	0.162 0.0443	0.162 0.0443	0.162 0.0443	0.162 0.0443	0.162 0.0443	0.162 0.0443	0.162C0.0425
1.200	0.135	0.0387	0.663	0.093	0.135 0.0387	0.135 0.0387	0.135 0.0387	0.135 0.0387	0.135 0.0387	0.135 0.0387	0.135 0.0387
1.250	0.108	0.0334	0.643	0.069	0.108 0.0334	0.108 0.0334	0.108 0.0334	0.108 0.0334	0.108 0.0334	0.108 0.0334	0.108 0.0334
1.300	0.082	0.0282	0.603	0.049	0.082 0.0282	0.082 0.0282	0.082 0.0282	0.082 0.0282	0.082 0.0282	0.082 0.0282	0.082 0.0282
1.350	0.058	0.0232	0.532	0.032	0.058 0.0232	0.058 0.0232	0.058 0.0232	0.058 0.0232	0.058 0.0232	0.058 0.0232	0.058 0.0232
1.400	0.034	0.0185	0.409	0.017	0.034 0.0185	0.034 0.0185	0.034 0.0185	0.034 0.0185	0.034 0.0185	0.034 0.0185	0.034 0.0185
1.450	0.012	0.0141	0.194	0.006	0.012 0.0141	0.012 0.0141	0.012 0.0141	0.012 0.0141	0.012 0.0141	0.012 0.0141	0.012 0.0141

PROPELLER OPEN-WATER AND CAVITATION CHARACTERISTICS FROM SUBROUTINE CAVKTQ

177.36-TON PLANING HULL FEASIBILITY MODEL GAWN-BURRILL PROPS SAMPLE (DEC 80)

****

LP/V13	LP/BPX	AP/V23	LP-FT	BPX-FT	BPA-FT	HM-FT	HT-FT	D-IN	P/D	EAR	NPR	ASH-DEG	LSH-FT	DSH IN	IOPT
5.54	4.98	4.91	101.85	20.47	16.28	5.57	4.77	60.0	1.40	1.000	3	14.4	25.57	5.44	0

DISPL-LBS	PROV-DAYS	OFFICERS	CPO	ENL-MEN	ACC.	GM-FT	KM-FT	KG-FT	LCG/LP	VOLH-FT3	VOLSS-FT3	NTB	IFRM
397286.	12.0	3.0	3.0	10.0	16.0	4.00	12.66	8.66	0.401	23361.	5000.	9	0

STRUCT.MAT.	MIN.LBS/FT2	SLOPE	DENS.LBS/FT3	STRESS-PSI	TRIM-DEG	R/W(SAV)	C-LOAD	H13-FT	RANGE-MILES
ALUM.	4.0	0.066667	166.	18000.	5.24 4.83	0.1330.109	0.723	0.00	799. 1000.

V-KT	FNV	SIGMA	H13-FT	RB/W	RA/W	RW/W	1-W	1-T	KT/JSQ	JT	EP	PC	OPC	T-LB	Q-FT.LB	RPM-P	EHP	DHP	BHP
DESIGN																			
45.0	3.12	0.48	5.66	0.1361	0.1496	0.1791	0.977	0.920	0.094C	1.199	0.663*	0.625	0.475	77339.	111181.	743.	9826.	15720.	16355.
CRUISE																			
30.0	2.08	1.06	7.36	0.1157	0.1240	0.1465	0.985	0.920	0.170	1.083	0.663	0.620	0.490	63248.	82181.	552.	5357.	8642.	8992.
10.0	0.69	8.28	5.66	0.0103	0.0108	0.0174	1.057	0.920	0.158	1.100	0.666	0.580	0.343	7499.	9850.	195.	212.	365.	380.
15.0	1.04	3.67	5.66	0.0537	0.0566	0.0665	1.059	0.920	0.267	0.984	0.635	0.551	0.445	28710.	35420.	327.	1216.	2207.	2296.
20.0	1.39	2.11	5.66	0.0901	0.0955	0.1086	1.047	0.920	0.251	0.998	0.640	0.562	0.466	46887.	58198.	425.	2647.	4710.	4901.
25.0	1.74	1.43	5.66	0.1022	0.1089	0.1253	1.017	0.920	0.197	1.052	0.657	0.594	0.485	54095.	68991.	489.	3818.	6426.	6685.
30.0	2.08	1.06	5.66	0.1157	0.1240	0.1437	0.985	0.920	0.167	1.087	0.664	0.621	0.499	62056.	80841.	550.	5256.	8470.	8812.
33.0	2.29	0.89	5.66	0.1230	0.1324	0.1540	0.975	0.920	0.151	1.108	0.667	0.630	0.503	66512.	87911.	588.	6197.	9841.	10239.
36.0	2.50	0.76	5.66	0.1300	0.1405	0.1642	0.970	0.920	0.137	1.129	0.669	0.635	0.503	70890.	95152.	627.	7205.	11354.	11812.
39.0	2.71	0.65	5.66	0.1350	0.1467	0.1723	0.970	0.920	0.122C	1.151	0.669	0.635	0.497	74394.	101751.	666.	8191.	12906.	13428.
42.0	2.92	0.55	5.66	0.1373	0.1501	0.1776	0.973	0.920	0.108C	1.174	0.668*	0.631	0.488	76704.	107301.	705.	9095.	14410.	14992.
45.0	3.12	0.48	5.66	0.1361	0.1496	0.1791	0.977	0.920	0.094C	1.199	0.663*	0.625	0.475	77339.	111181.	743.	9826.	15720.	16355.
MAXIMUM																			
36.8	2.55	0.73	5.66	0.1316	0.1424	0.1665	0.970	0.920	0.133C	1.134	0.669	0.635	0.502	71916.	96979.	637.	7471.	11765.	12240.

	V-KT	NO.	HP	RPM-E	SFC	RANGE-MI.	SW	WE	GR	WG	WPR	WSH	WB	GEARC	GEARK	GEARE
DIESEL	36.8	3.	4080.	1900.	0.370	799.	3.62	14771.	2.6	3500.	1044.	2018.	1283.	16000.	200.	0.9
CRUISE	30.0				0.359	1000.										

PAYLOAD REQUIREMENTS WT= 34720. LBS VOL= 250. FT3 VCG= 4.00 FT + HULL DEPTH PAYLOAD DENSITY=138.88 LBS/FT3

VEHICLE DENSITY = 17.01 LBS/FT3 PAYLOAD DENSITY = 11.16 LBS/FT3	GROUP 1 STRUCT.	GROUP 2 PROP.	GROUP 3 ELEC.	GROUP 4 COMM.	GROUP 5 AUX.SYS.	GROUP 6 OUTFIT	EMPTY SHIP	USEFUL LOAD	CREW +PROV.	FUEL LOAD	PAY-LOAD
WEIGHT/TOTAL WT. (397286. LBS)	0.2226	0.2270	0.0373	0.0073	0.0506	0.0556	0.6004	0.3996	0.0273	0.2849	0.0874
VCG/HULL DEPTH (14.00 FT)	0.6093	0.5517	0.8068	0.8418	0.6615	0.7588	0.6209	0.6159	0.4184	0.4286	1.2884
VOLUME/TOTAL VOL.(28361. FT3)	0.1169	0.2799	0.0000	0.1036	0.0788	0.2174	0.7966	0.2034	0.0134	0.0804	0.1097
COST - MILLIONS OF FY77 DOLLARS	0.854	2.095	0.573	0.086	0.542	0.398	4.548				0.084

	FIRST UNIT	AVERAGE UNIT	PERSONNEL PAY, ETC.	MAINTE-NANCE	OPERATIONS W/O ENERGY	MAJOR SUPPORT	FUEL COST	TOTAL COST
LIFE COSTS - MILLIONS	4.633	4.187	1.132	0.292	3.268	0.795	7.047	16.722

PAGE 1 FROM SUBROUTINE PRTOUT

177.36-TON PLANING HULL FEASIBILITY MODEL GAWN-BURRILL PROPS SAMPLE (DEC 80)

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	BSCI NO.	WEIGHT FRACTION	VOLUME FRACTION	VCG / HULL DEPTH	WEIGHT (LBS)	WEIGHT (L.TONS)	WEIGHT (M.TONS)	VOLUME (FT**3)	VOLUME (M**3)	MULT
LOADS										
USEFUL LOAD	0	0.3996	0.2034	0.6159	158736.	70.864	72.001	5769.0	163.36	1.00
FUEL	0	0.2849	0.0804	0.4286	113171.	50.523	51.334	2279.0	64.53	1.00
CREW AND EFFECTS	1	0.0108	0.0002	0.7320	4301.	1.920	1.951	5.5	0.16	1.00
PERSONNEL STORES	6	0.0031	0.0101	0.5360	1221.	0.545	0.554	287.8	8.15	1.00
POTABLE WATER	12	0.0134	0.0030	0.1380	5322.	2.376	2.414	85.6	2.42	1.00
PAYLOAD	0	0.0874	0.1097	1.2884	34720.	15.500	15.749	3111.1	88.10	1.00
HULL STRUCTURE										
	1	0.2226	0.1169	0.6093	88453.	39.488	40.122	3316.0	93.90	1.10
	100	0.0280	0.0024	0.1365	11143.	4.975	5.054	67.1	1.90	1.00
	100	0.0273	0.0219	0.6335	10862.	4.849	4.927	622.3	17.62	1.00
	101	0.0412	0.0346	0.5922	16353.	7.300	7.418	981.2	27.78	1.00
	103	0.0000	0.0000	0.0000	0.	0.000	0.000	0.0	0.00	1.00
	103	0.0167	0.0134	0.4956	6639.	2.964	3.012	381.1	10.79	1.00
	107	0.0250	0.0213	0.9826	9938.	4.437	4.508	603.3	17.08	1.00
	114	0.0228	0.0186	0.5786	9069.	4.049	4.114	526.9	14.92	1.00
	114	0.0054	0.0047	0.4266	2146.	0.958	0.973	134.1	3.80	1.00
	111	0.0126	0.0000	1.4286	5000.	2.232	2.268	0.0	0.00	1.00
	112	0.0081	0.0000	0.1500	3218.	1.437	1.460	0.0	0.00	1.00
	113	0.0056	0.0000	0.7800	2214.	0.988	1.004	0.0	0.00	1.00
	198	0.0096	0.0000	0.6093	3829.	1.709	1.737	0.0	0.00	1.00
	199	0.0202	0.0000	0.6093	8041.	3.590	3.647	0.0	0.00	0.00
PROPULSION										
	2	0.2270	0.2799	0.5517	90192.	40.264	40.911	7937.0	224.75	1.10
	201	0.1380	0.2644	0.6150	54813.	24.470	24.863	7500.0	212.38	1.00
	203	0.0328	0.0000	0.0000	13033.	5.818	5.912	0.0	0.00	1.00
	204205	0.0138	0.0154	1.1300	5484.	2.448	2.487	437.0	12.37	1.00
	206	0.0035	0.0000	0.6150	1371.	0.612	0.622	0.0	0.00	1.00
	209	0.0025	0.0000	0.6150	987.	0.441	0.448	0.0	0.00	1.00
	210	0.0052	0.0000	0.6150	2084.	0.930	0.945	0.0	0.00	1.00
	211	0.0025	0.0000	0.6150	987.	0.441	0.448	0.0	0.00	1.00
	250251	0.0081	0.0000	0.6150	3235.	1.444	1.467	0.0	0.00	1.00
	299	0.0206	0.0000	0.5517	8199.	3.660	3.719	0.0	0.00	0.00
ELECTRIC PLANT										
	3	0.0373	0.0000	0.8068	14811.	6.612	6.718	0.0	0.00	1.10
	300	0.0140	0.0000	0.7729	5578.	2.490	2.530	0.0	0.00	1.00
	301	0.0028	0.0000	0.7860	1109.	0.495	0.503	0.0	0.00	1.00
	302	0.0136	0.0000	0.6990	5400.	2.411	2.449	0.0	0.00	1.00
	303	0.0035	0.0000	1.3830	1378.	0.615	0.625	0.0	0.00	1.00
	399	0.0034	0.0000	0.8068	1346.	0.601	0.611	0.0	0.00	0.00

PAGE 2 FROM SUBROUTINE PRTOUT

177.36-TON PLANING HULL FEASIBILITY MODEL GAWN-BURRILL PROPS SAMPLE (DEC 80)

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	BSCI NO.	WEIGHT FRACTION	VOLUME FRACTION	VCG / HULL DEPTH	WEIGHT (LBS)	WEIGHT (L.TONS)	WEIGHT (M.TONS)	VOLUME (FT**3)	VOLUME (M**3)	MULT
COMMUNICATION AND CONTROL										
	4	0.0073	0.1036	0.8418	2905.	1.297	1.318	2938.2	83.20	1.10
	400	0.0006	0.1000	1.4487	222.	0.099	0.101	2836.1	80.31	1.00
	401	0.0061	0.0036	0.7860	2418.	1.080	1.097	102.1	2.89	1.00
	499	0.0007	0.0000	0.8418	264.	0.118	0.120	0.0	0.00	0.00
AUXILIARY SYSTEMS										
	5	0.0506	0.0788	0.6615	20114.	8.979	9.123	2234.6	63.28	1.10
	500502	0.0058	0.0000	0.8446	2287.	1.021	1.037	0.0	0.00	1.00
	501	0.0040	0.0300	1.0154	1588.	0.709	0.720	850.8	24.09	1.00
	503	0.0000	0.0000	0.4650	0.	0.000	0.000	0.0	0.00	0.00
	505	0.0024	0.0184	0.8573	957.	0.427	0.434	522.4	14.79	1.00
	506	0.0064	0.0000	0.6689	2541.	1.134	1.153	0.0	0.00	1.00
	507	0.0021	0.0000	0.7500	832.	0.372	0.377	0.0	0.00	1.00
	508	0.0031	0.0044	0.2920	1232.	0.550	0.559	124.2	3.52	1.00
	509	0.0021	0.0000	0.6679	824.	0.368	0.374	0.0	0.00	1.00
	510	0.0005	0.0000	0.9806	212.	0.094	0.096	0.0	0.00	1.00
	511	0.0001	0.0000	0.4180	34.	0.015	0.015	0.0	0.00	1.00
	513	0.0000	0.0000	0.0000	0.	0.000	0.000	0.0	0.00	0.00
	517	0.0000	0.0000	0.5400	0.	0.000	0.000	0.0	0.00	0.00
	518	0.0039	0.0127	0.6560	1532.	0.684	0.695	360.9	10.22	1.00
	519	0.0100	0.0000	0.3820	3980.	1.777	1.805	0.0	0.00	1.00
	520	0.0032	0.0031	0.7020	1271.	0.567	0.576	88.7	2.51	1.00
	521	0.0000	0.0000	1.0000	0.	0.000	0.000	0.0	0.00	0.00
	528	0.0004	0.0017	0.8070	159.	0.071	0.072	47.6	1.35	1.00
	550	0.0002	0.0040	0.5335	69.	0.031	0.031	113.4	3.21	1.00
	551	0.0019	0.0000	0.9039	768.	0.343	0.348	0.0	0.00	1.00
	599	0.0046	0.0045	0.6615	1829.	0.816	0.829	126.5	3.58	0.00
OUTFIT AND FURNISHINGS										
	6	0.0556	0.2174	0.7588	22075.	9.855	10.013	6166.4	174.61	1.10
	600	0.0032	0.0000	1.0640	1263.	0.564	0.573	0.0	0.00	1.00
	601	0.0020	0.0000	1.2480	800.	0.357	0.363	0.0	0.00	1.00
	602	0.0003	0.0000	1.4287	100.	0.045	0.045	0.0	0.00	1.00
	603	0.0058	0.0395	0.4690	2310.	1.031	1.048	1120.7	31.73	1.00
	604	0.0021	0.0000	0.9556	820.	0.366	0.372	0.0	0.00	1.00
	605	0.0054	0.0000	0.6366	2127.	0.950	0.965	0.0	0.00	1.00
	606	0.0059	0.0000	0.8845	2338.	1.044	1.060	0.0	0.00	1.00
	607	0.0176	0.0000	0.8446	6988.	3.120	3.170	0.0	0.00	0.50
	608	0.0000	0.0000	0.6330	0.	0.000	0.000	0.0	0.00	0.00
	609	0.0000	0.0000	0.7280	0.	0.000	0.000	0.0	0.00	0.00
	610	0.0000	0.0000	0.8021	0.	0.000	0.000	0.0	0.00	0.00
	611	0.0017	0.0167	0.9636	657.	0.293	0.298	473.6	13.41	1.00
	612	0.0049	0.1472	0.8772	1949.	0.870	0.884	4175.3	118.23	0.70
	613	0.0018	0.0017	1.0221	717.	0.320	0.325	47.8	1.35	1.00
	614	0.0000	0.0000	0.9171	0.	0.000	0.000	0.0	0.00	0.00
	699	0.0051	0.0123	0.7588	2007.	0.896	0.910	349.0	9.88	0.00

PAGE 3 FROM SUBROUTINE PRTOUT

177.36-TON PLANING HULL FEASIBILITY MODEL GAWN-BURRILL PROPS SAMPLE (DEC 80)

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DISPL-LB	DISPL-TONS	LP-FT	BPX-FT	H-FT	HH-FT	IZS-FT	KB-FT	BM-FT	KM-FT	GM-FT	KG-FT	LCG-FT
397286.	177.36	101.85	20.47	5.57	14.00	0.97	3.62	9.04	12.66	4.00	8.66	40.84

X/LP	X-FT	ZS-FT	ZC-FT	ZK-FT	YS-FT	YC-FT	YK-FT	BETA-DEG	AS-FT2	VOL-FT3
0.000	0.00	11.19	2.65	0.81	10.66	10.23	0.00	10.20	197.79	0.00
0.025	2.55	11.35	2.70	0.77	10.72	10.23	0.00	10.69	201.49	508.34
0.050	5.09	11.51	2.75	0.73	10.84	10.23	0.00	11.18	205.89	1026.68
0.075	7.64	11.63	2.80	0.69	10.94	10.23	0.00	11.66	209.28	1555.45
0.100	10.18	11.76	2.84	0.65	11.04	10.23	0.00	12.11	213.05	2093.04
0.150	15.28	12.05	2.94	0.56	11.24	10.23	0.00	13.08	220.84	3197.71
0.200	20.37	12.35	3.04	0.48	11.45	10.23	0.00	14.06	229.26	4343.53
0.250	25.46	12.67	3.14	0.39	11.66	10.21	0.00	15.07	237.78	5532.70
0.300	30.55	12.96	3.24	0.31	11.84	10.18	0.00	16.05	245.42	6763.42
0.350	35.65	13.20	3.33	0.23	12.04	10.14	0.00	17.05	252.21	8030.87
0.400	40.74	13.51	3.44	0.14	12.25	10.05	0.00	18.15	259.90	9334.44
0.450	45.83	13.77	3.54	0.06	12.49	9.94	0.00	19.30	266.57	10675.41
0.500	50.92	14.00	3.63	0.00	12.70	9.74	0.00	20.45	270.97	12045.07
0.550	56.02	14.22	3.73	0.00	12.86	9.42	0.00	21.60	272.20	13429.48
0.600	61.11	14.42	3.83	0.00	13.07	8.93	0.00	23.22	271.09	14813.82
0.650	66.20	14.64	3.93	0.00	13.11	8.31	0.00	25.32	266.64	16184.44
0.700	71.30	14.81	4.03	0.00	13.04	7.58	0.00	28.00	258.16	17522.43
0.750	76.39	14.94	4.12	0.05	12.74	6.70	0.00	31.32	243.46	18802.32
0.800	81.48	15.09	4.22	0.11	12.20	5.72	0.00	35.72	224.39	19995.46
0.850	86.57	15.16	4.35	0.24	11.25	4.53	0.00	42.20	195.78	21069.37
0.875	89.12	15.19	4.41	0.45	10.65	3.89	0.00	45.53	178.54	21546.33
0.900	91.66	15.20	4.48	0.73	9.90	3.13	0.00	50.15	158.04	21975.54
0.925	94.21	15.22	4.56	1.31	9.11	2.45	0.00	53.04	137.62	22351.94
0.950	96.76	15.22	4.63	2.14	8.12	1.69	0.00	55.83	114.28	22673.24
0.975	99.30	15.19	4.72	3.18	6.93	1.46	0.00	46.40	95.38	22939.22
1.000	101.85	15.16	4.79	4.79	5.58	0.00	0.00	0.00	63.30	23144.05
1.080	110.00	14.89	0.00	13.92	0.00	0.00	0.00	0.00	0.00	23361.20

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		SEA STATE	1	2	3	4	1	2	3	4		1	2	3	4	1	2	3	4
		H13-FT	1.92	4.13	5.66	7.36	1.92	4.13	5.66	7.36		1.92	4.13	5.66	7.36	1.92	4.13	5.66	7.36
	SAVITSKY		CG ACC (G)				BOW ACC (G)				FIXED	CG ACC (G)				BOW ACC (G)			
V-KT	R/W	TRIM									TRIM								
10.00	0.0574	3.04	0.08	0.17	0.23	0.30	0.36	0.77	1.05	1.37	2.50	0.08	0.16	0.22	0.29	0.34	0.73	0.99	1.29
15.00	0.0670	3.33	0.12	0.25	0.35	0.45	0.50	1.07	1.47	1.91	2.50	0.11	0.24	0.33	0.43	0.46	0.98	1.35	1.75
20.00	0.0793	3.74	0.16	0.34	0.47	0.61	0.64	1.38	1.89	2.46	2.50	0.15	0.32	0.44	0.58	0.57	1.22	1.67	2.17
25.00	0.0937	4.26	0.20	0.44	0.60	0.78	0.79	1.70	2.33	3.03	2.50	0.19	0.40	0.55	0.72	0.67	1.44	1.98	2.57
30.00	0.1085	4.83	0.25	0.54	0.74	0.96	0.95	2.04	2.79	3.63	2.50	0.23	0.48	0.66	0.86	0.77	1.65	2.27	2.95
33.00	0.1164	5.11	0.28	0.60	0.82	1.07	1.04	2.23	3.06	3.98	2.50	0.25	0.53	0.73	0.95	0.83	1.78	2.43	3.17
36.00	0.1227	5.29	0.31	0.66	0.90	1.17	1.12	2.41	3.31	4.30	2.50	0.27	0.58	0.80	1.04	0.88	1.90	2.60	3.38
39.00	0.1273	5.37	0.33	0.71	0.98	1.27	1.20	2.58	3.53	4.59	2.50	0.29	0.63	0.86	1.12	0.94	2.01	2.76	3.59
42.00	0.1306	5.34	0.36	0.77	1.05	1.37	1.26	2.72	3.73	4.84	2.50	0.32	0.68	0.93	1.21	0.99	2.13	2.92	3.79
45.00	0.1330	5.24	0.38	0.82	1.12	1.46	1.32	2.84	3.90	5.07	2.50	0.34	0.73	1.00	1.30	1.04	2.24	3.07	3.99

PAGE 4 FROM SUBROUTINE PRTOUT

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SUB PHFM.BI

$JOB TO LOAD PLANING HULL FEASIBILITY MODEL


.R LOAD
*PHFM.LD,LPT:<PHMOPT,YINTE,MINP,YINTX/O
*READIN,OWKTQ2,CAVKT2
*PARENT,NEWHUL,CREWSS,POWER,PROPS,WJETS
*NEWVOL,STPHA,LOADS,ELECPL,COMCON,AUXIL,OUTFIT
*TOTALS,COSTS
*PROUT1,PROUT2/O
*TQMAX2,PINTP2,SIMPUN
*PHRES,PRCOEF,SAVIT,C1DSF,DISCOT,DISSER,LAGRAN,UNS/O
*+

LOADER V24A    19-DEC-80

SYMBOL VALUE LVL OVLY
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SYMBOL	VALUE	LVL	OVLY	SYMBOL	VALUE	LVL	OVLY	SYMBOL	VALUE	LVL	OVLY
ABS	31027	0	00	B25	22307	0	00	MINP	25736	0	00
ALOG	30142	0	00	B26	22356	0	00	MINO	31375	0	00
ALOG10	30401	0	00	B27	22417	0	00	MIN1	31375	0	00
AMINO	31300	0	00	B28	22554	0	00	NEWHUL	32775	1	01
AMIN1	31300	0	00	B29	23101	0	00	NEWVOL	32000	1	02
ARGERR	00204	0	00	B30	23332	0	00	OUTFIT	51146	1	02
ATAN	27616	0	00	B31	23475	0	00	OWKTQ	37151	1	00
AUXIL	47302	1	02	B32	23574	0	00	PARENT	32000	1	01
B01	14375	0	00	B33	24272	0	00	PHRES	53000	2	01
B02	14430	0	00	B34	24674	0	00	POWER	37155	1	01
B03	14460	0	00	B35	25160	0	00	PRCOEF	56614	2	01
B04	14510	0	00	B36	25232	0	00	PRINTP	53363	2	00
B05	14733	0	00	B37	25262	0	00	PROPS	44606	1	01
B06	16022	0	00	B38	25315	0	00	PROUT2	43631	1	04
B07	16647	0	00	B39	25337	0	00	PRTOUT	32000	1	04
B08	17417	0	0C	B40	25516	0	00	READIN	32000	1	00
B09	20365	0	00	B41	25543	0	00	SAVIT	57302	2	01
B10	20412	0	00	CAVKTQ	43620	1	00	SIMPUN	56544	2	00
B11	20442	0	00	COMCON	46713	1	02	SIN	30502	0	00
B12	20467	0	00	COS	30043	0	00	SQRT	27346	0	00
B13	20517	0	00	COSTS	35742	1	03	STRUCT	33267	1	02
B14	20547	0	00	CREWSS	36373	1	01	TAN	30711	0	00
B15	20571	0	00	C1DSF	62227	2	01	TOTALS	32000	1	03
B16	20624	0	00	DISCOT	62550	2	01	TQMAX	53000	2	00
B17	20654	0	00	DISSER	64165	2	01	UNS	65244	2	01
B18	20707	0	00	ELECPL	46172	1	02	WJETS	47134	1	01
B19	21762	0	00	EXIT	00223	0	00	YINTE	14041	0	00
B20	22023	0	00	EXP	31413	0	00	YINTX	26461	0	00
B21	22064	0	00	EXP3	31152	0	00	#MAIN	10000	0	00
B22	22136	0	00	IABS	31027	0	00				
B23	22210	0	00	LAGRAN	64677	2	01				
B24	22251	0	00	LOADS	45152	1	02				

66000 = 1ST FREE LOCATION

LVL	OVLY	LENGTH
0	00	31736
1	00	20764
1	01	17664
1	02	20560
1	03	06056
1	04	20076
2	00	04631
2	01	12541

LOAD MAP FOR DEC PDP/8 COMPUTER

```
.R FRTS
*PHFM                  (This is the object program.)
*INPHFM.DA/5           (This is the input file.)
*OTPHFM.DA<(6C)        (This is the output file.)
*$
```

```
 PLANING HULL FEASIBILITY MODEL            SAMPLE     ( DEC 80 )

READIN COMPLETED

PARENT COMPLETED

NEWHUL COMPLETED

CREWSS COMPLETED

POWER  COMPLETED

NEWVOL COMPLETED

STRUCT COMPLETED               This information printed at console.

LOADS  COMPLETED

ELECPL COMPLETED

COMCON COMPLETED

AUXIL  COMPLETED

OUTFIT COMPLETED

TOTALS COMPLETED

COSTS  COMPLETED

PRTOUT COMPLETED

END OF PROGRAM

.
```

SAMPLE RUN ON DEC PDP/8 COMPUTER AT NAVSEADET NORFOLK

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